State of Iowa

Iowa Comprehensive Emergency Plan

Part B: Iowa Hazard Mitigation Plan

September 2023

State of Iowa Hazard Mitigation Plan
Chapter 3: Hazard Analysis and Risk Assessment

3. Hazard Analysis and Risk Assessment

3.1. Hazard Analysis and Risk Assessment Approach

Iowa's foundation for hazard mitigation is based on a hazard analysis and risk assessment (HARA) that is comprehensive and multi-hazard. This means that multiple hazards that can occur anywhere in the state are considered and analyzed, and that the risk that each hazard poses is assessed in terms of a disaster or emergency that can be created from that hazard. The comprehensive planning approach depends upon a clear understanding of what hazards exist, what risks they pose, and who and what can be impacted.

A. Hazard Overviews or Profiles

The 2018 *Iowa Hazard Mitigation Plan* identified 20 hazards that pose a measure of risk to Iowa. Of those, 13 are considered natural hazards, meaning they "are a source of harm or difficulty created by a meteorological, environmental, or geological phenomenon or combination of phenomena"[1]. By this definition, "natural" does not include biological hazards, such as disease. To comply with 44 CFR 201.4 (c) (2), this plan must contain an "overview of the type and location of all natural hazards that can affect the state." In section 3.3 profiles, or overviews, of each of the following natural hazards determined to be able to affect the state of Iowa will be presented:

1. Drought
2. Tornadoes and other High Wind Events (including derechos)
3. Flooding-River
4. Flooding-Flash
5. Severe Winter Storms
6. Hail and Lightning storms
7. Excessive Heat
8. Dam and Levee failure (relates to natural hazard of flooding)
9. Landslides
10. Earthquake
11. Wildfire, including Grass Fire
12. Sinkholes
13. Expansive Soils

The natural hazard profiles include information on the nature of each natural hazard, the locations or areas where they are found, and information on previous occurrences of hazard events. Using best available information, the probability of future hazard events is also provided for each natural hazard profiled in section 3.3.

Section 3.4 includes a brief overview of several "non-natural" hazards that affect Iowa, namely:

1. Animal/Crop/Plant Disease
2. Pandemic Human Disease
3. Hazardous Materials

[1] *U.S. Department of Homeland Security Risk Lexicon*, 2010

4. Infrastructure Failure
5. Radiological Incident
6. Terrorism
7. Transportation Incident

These seven hazards plus the thirteen natural hazards are the same 20 hazards used in the Threat and Hazard Identification and Risk Assessment (THIRA) for Iowa. The THIRA evaluates the disasters that may arise from hazards and evaluates what is needed to respond to such disasters. Upon evaluating what is needed for response to a serious scenario of each hazard, a comparison is then made to the capabilities within the state to deal with and respond to each scenario. Thus, the THIRA determines which capabilities need to be improved and how much. Whereas the THIRA evaluates **what is needed to respond** to the identified hazard risks, the purpose of this plan is to evaluate **what can be done to mitigate** the risks of each hazard.

B. Hazard Probabilities

For many of the natural hazards, the best available data with which to estimate probability is often based on past events. Though certainly not the only source of past event data, a key source for this information comes from the Storm Events Database of the National Centers for Environmental Information (NCEI)[2]. NCEI data was analyzed for dam and levee failure, drought, extreme/excessive heat, riverine flooding, flash flooding, winter weather, hail, lightning, tornadoes, and wind. As NCEI information is used for so many hazards, it is important to note the following about the information in the NCEI Storm Events Database:

- From 1950 through 1954, only tornado events were recorded.
- From 1955 through 1992, only tornado, thunderstorm, wind, and hail events were keyed from the paper publications into digital data.
- From 1993 to 1995, only tornado, thunderstorm, wind, and hail events have been extracted from the unformatted text files.
- From 1996 to present, 48 event types were recorded as defined in NWS Directive 10-1605.

Probability of future hazard events is not solely based on rates of historical past occurrence. For instance, in areas of the state where hydrologic and hydraulic studies have been done, riverine flood hazards are based on scientific modeling. Geologic sources and experts have been consulted to illustrate locations of higher probability of earthquakes, expansive soils, sinkholes, and landslides.

C. Changes in Climate and Development

Besides considering historical past occurrence and scientific modeling to estimate probability of hazard events, one should consider how trends in climate change, land use, and development may alter hazard risk. In order to adequately inform and understand future probability better, climate change trends in Iowa and their potential impact on future hazard events are explored in detail in section 3.2.

[2] Storm Event Database of the National Centers for Environmental Information. https://www.ncdc.noaa.gov/stormevents/

Also explored in section 3.2 are changes in the built environment throughout the state. The effects of development do not change the location and extent of hazards as much as they change the location and amount of vulnerability to hazard events.

D. Vulnerability

Vulnerability is a major component in the risk assessment profile of each natural hazard found in section 3.3. Each natural hazard profile summarizes the jurisdictions most vulnerable to the hazard. These vulnerability summaries are based on assessments found in various local hazard mitigation plans as well as information from national and state sources. These sources ascertain vulnerability not just on potential dollar losses but also on a variety of factors which may include social as well as economic factors.

While each natural hazard profile summarizes the hazard vulnerability of jurisdictions in the state, none of the hazard profiles in section 3.3 contain analyses of potential impacts to State of Iowa facilities. Such an analysis is presented, but it is presented in its own section where a summary is given of the potential dollar losses to State facilities due to the various natural hazards. This vulnerability analysis of State facilities is found in section 3.5.

3.2. Recent and Projected Changes and Their Impact on Risk

3.2.1. Changes to the Built Environment

Development and changes in land use and the built environment can increase hazard risks for jurisdictions experiencing such growth and change. Where such development has recently occurred in areas identified as higher risk for a particular hazard is of especial concern. For instance, development in flood hazard areas means more exposure and vulnerability and more risk to manage. Jurisdictions should be mindful as development encroaches closer and closer to areas, like flood hazard areas, that have a higher probability of experiencing a disastrous hazard event. Besides flooding, other hazards with geographic areas of higher risk identified in Iowa are dam or levee failure, landslide, earthquake, wildfire, sinkhole and expansive soils.

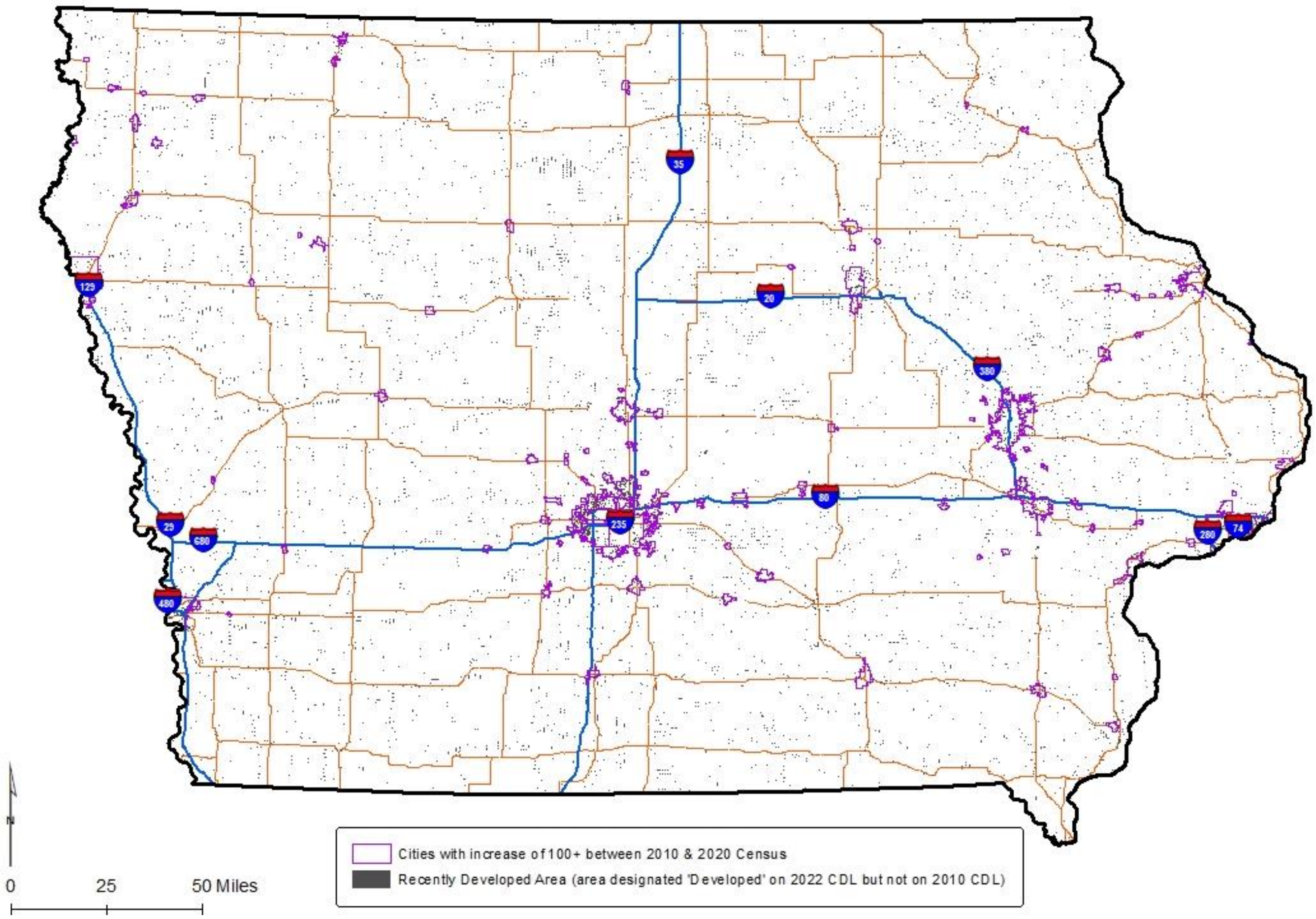
This section will summarize where recent development has occurred and where it is projected in Iowa. Different maps will be presented to illustrate how these growth areas compare to areas with more potential for landslides, wildfires, riverine flooding and earthquake damage. Also, those areas where growth and development are occurring will be compared to where levee-protected areas, sinkholes (and abandoned mines), and expansive soils are found throughout the state. This section will not contain maps or analysis of how dam-protected areas compare with areas of recent development. When development moves into such areas, the potential risk rating of the dam is changed, and then it falls under different rules and regulation. If development comes to a dam-protected area such that failure of the dam may create a serious threat of loss of human life, the dam is classified as high hazard potential. Such high hazard potential dams are identified in the Dam and Levee Failure hazard profile in Section 3.3.

As for Iowa’s other natural hazards (drought, excessive heat, severe winter storms, lightning, hail, and tornado and other wind hazards), they do not necessarily have particular geographic areas where hazard event probability is considerably greater than event probability elsewhere in Iowa. But, changes in population demographics may increase the exposure and vulnerability of certain populations to such hazards. For example, wherever more people go, those places will have more exposure and vulnerability to the impacts of hail or excessive heat. How such changes in population demographics have affected vulnerability to these other hazards will be presented in the hazard profiles in section 3.3.

A. Recently Developed Land in Areas with Greater Hazard Potential

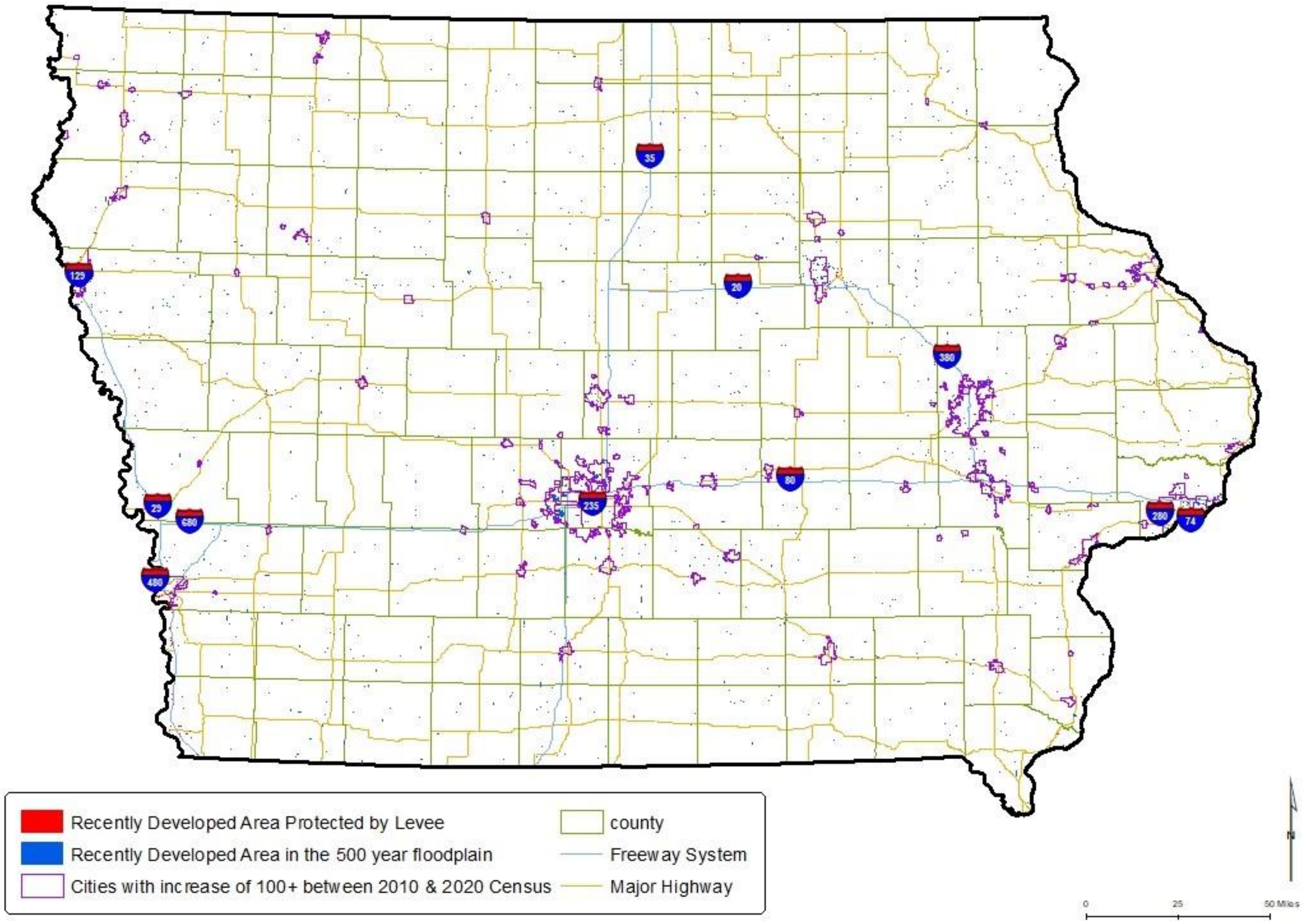
Using satellite imagery, the US Department of Agriculture annually updates a digital inventory what land is used to produce different crops. This Crop Data Layer (CDL) also includes what land is “Developed”. By comparing what land is currently “developed” as opposed to what was “developed” ten or twelve years ago, we can ascertain the areas that have recently been developed. The map below shows land that has recently changed from undeveloped (in 2010) to developed (in 2022) based on the CDL maps.

Areas of Recent Growth and Development

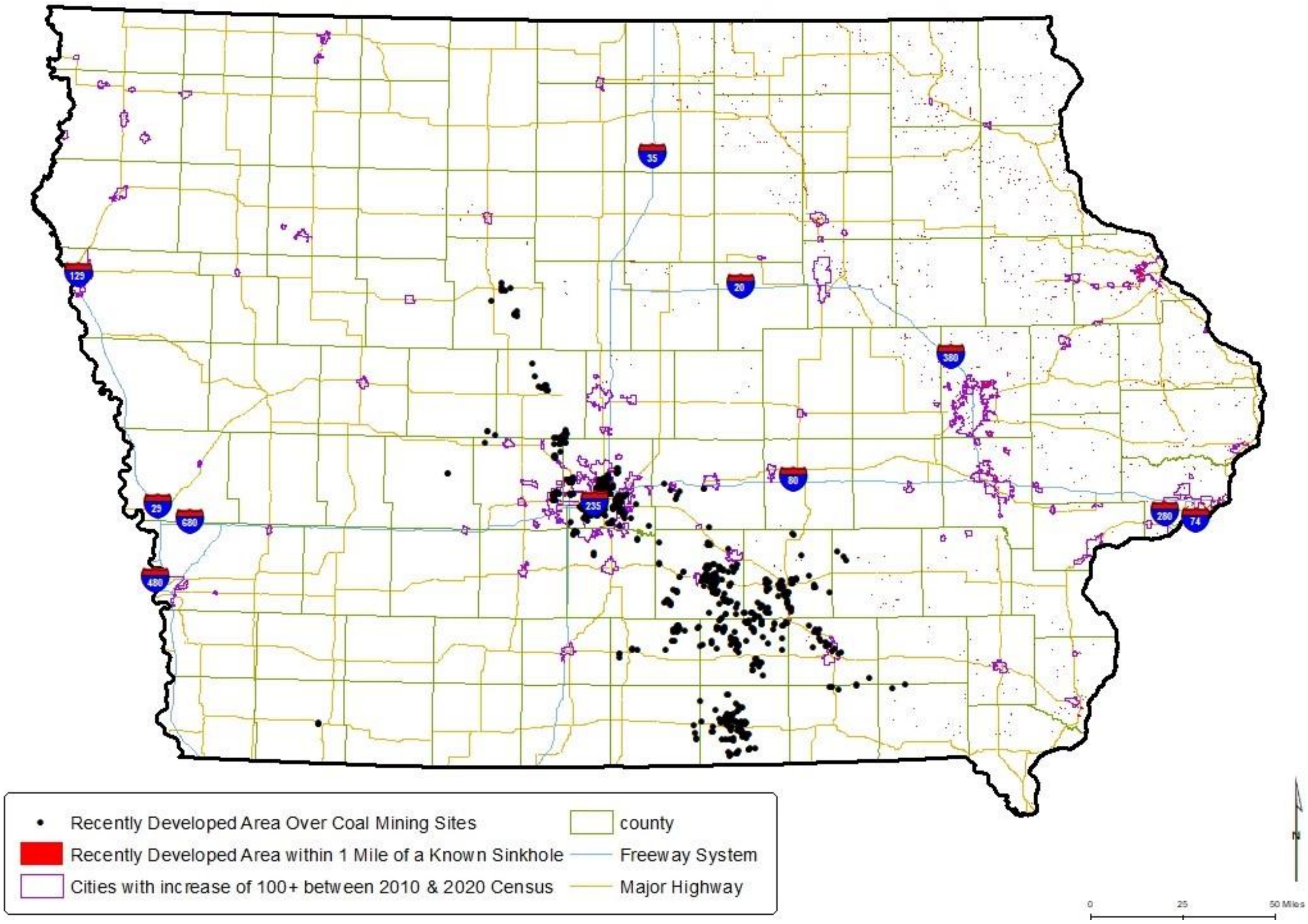


Analyses were done using geographic information systems (GIS) whereby this inventory of recently developed land was overlaid with areas having a greater potential of one of the following hazards: riverine flooding, sinkhole collapse, landslide, wildfire, and levee failure. The hazard potential areas were taken from various sources, and more details on each of the hazard data sources can be found in the hazard profiles of each respective hazard in section 3.3. The results of the analyses are shown in the following three maps.

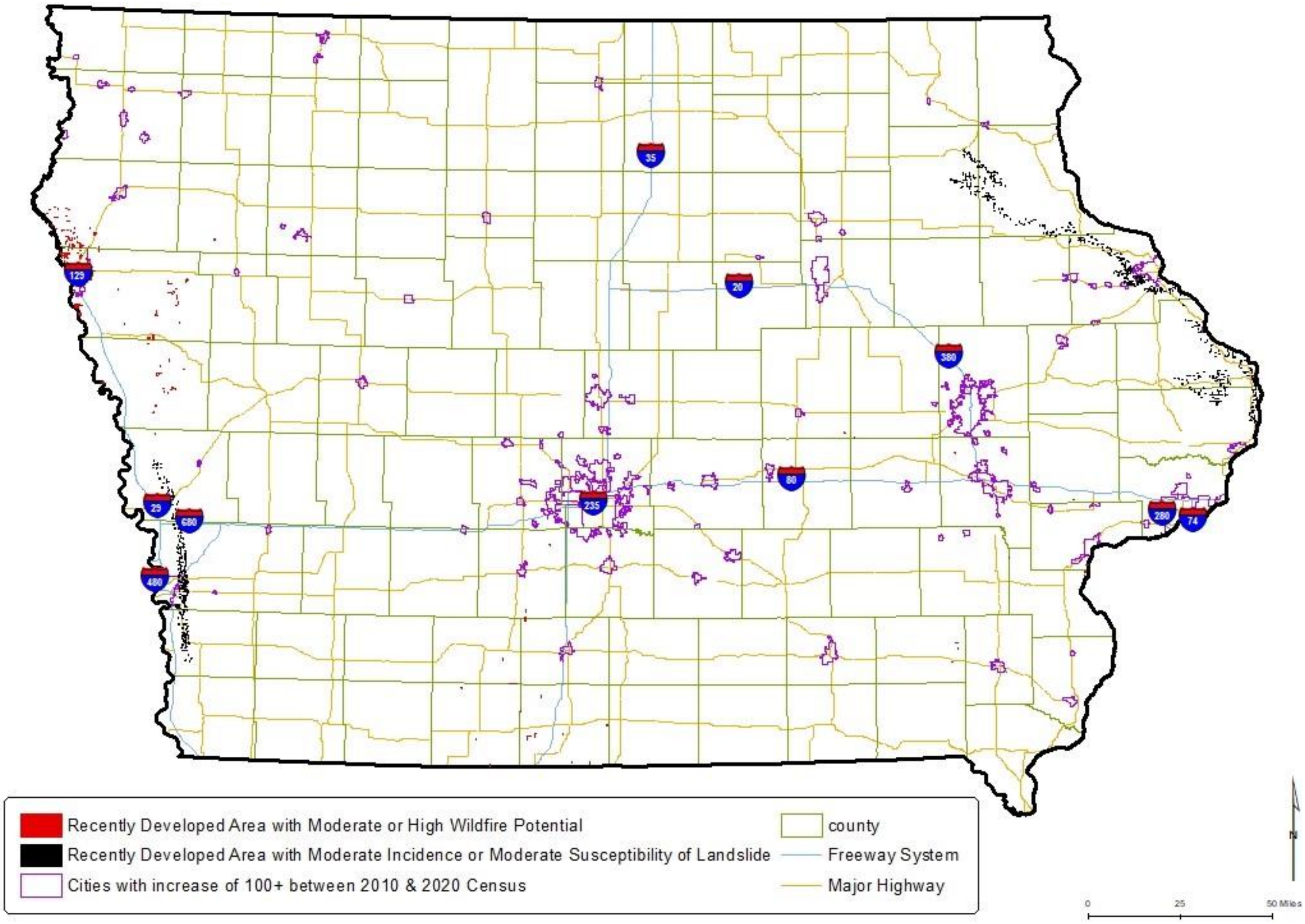
Recently Developed Land in Areas with Greater Potential for Flooding



Recently Developed Land in Areas with Greater Potential for Sinkholes



Recently Developed Land in Areas with Greater Wildfire or Landslide Potential

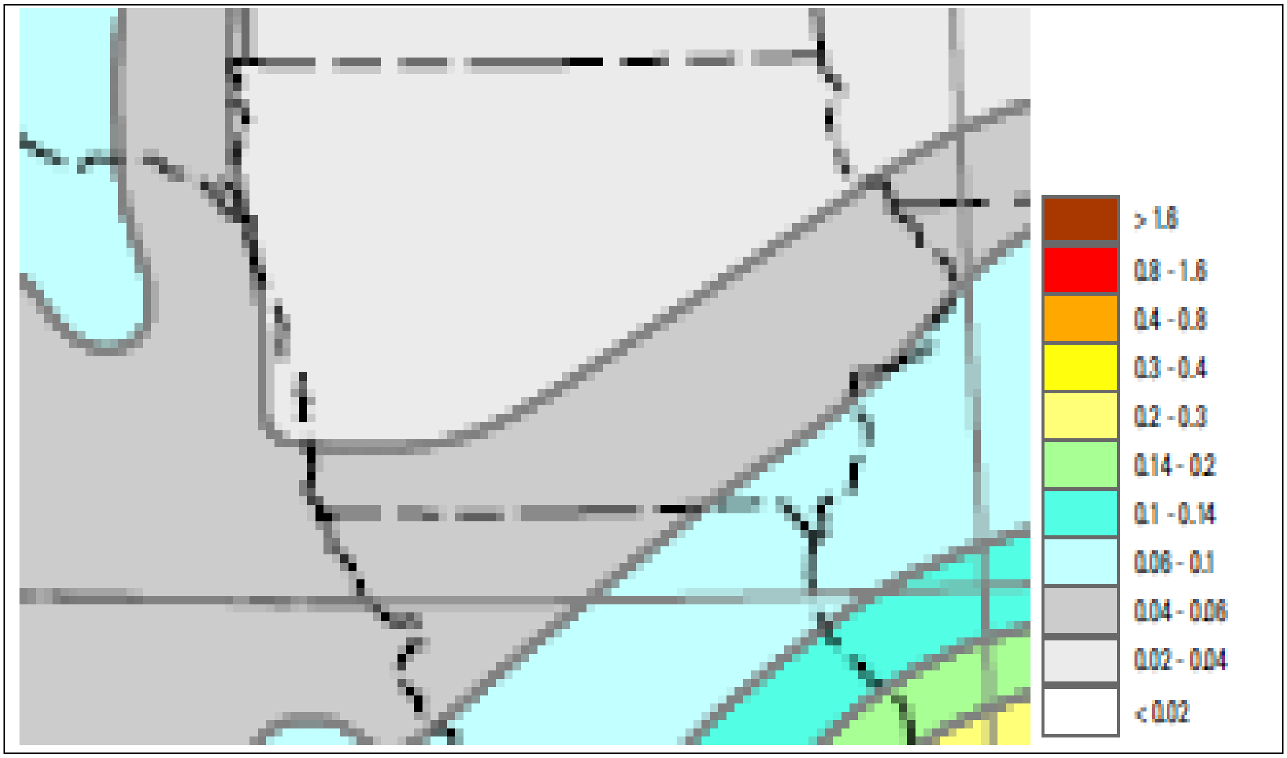


There are other hazard-prone areas for which the same GIS analysis could not be completed (because of lack of appropriate data). However, the following maps help illustrate where more hazard-prone areas are located in Iowa for earthquakes and expansive soils.

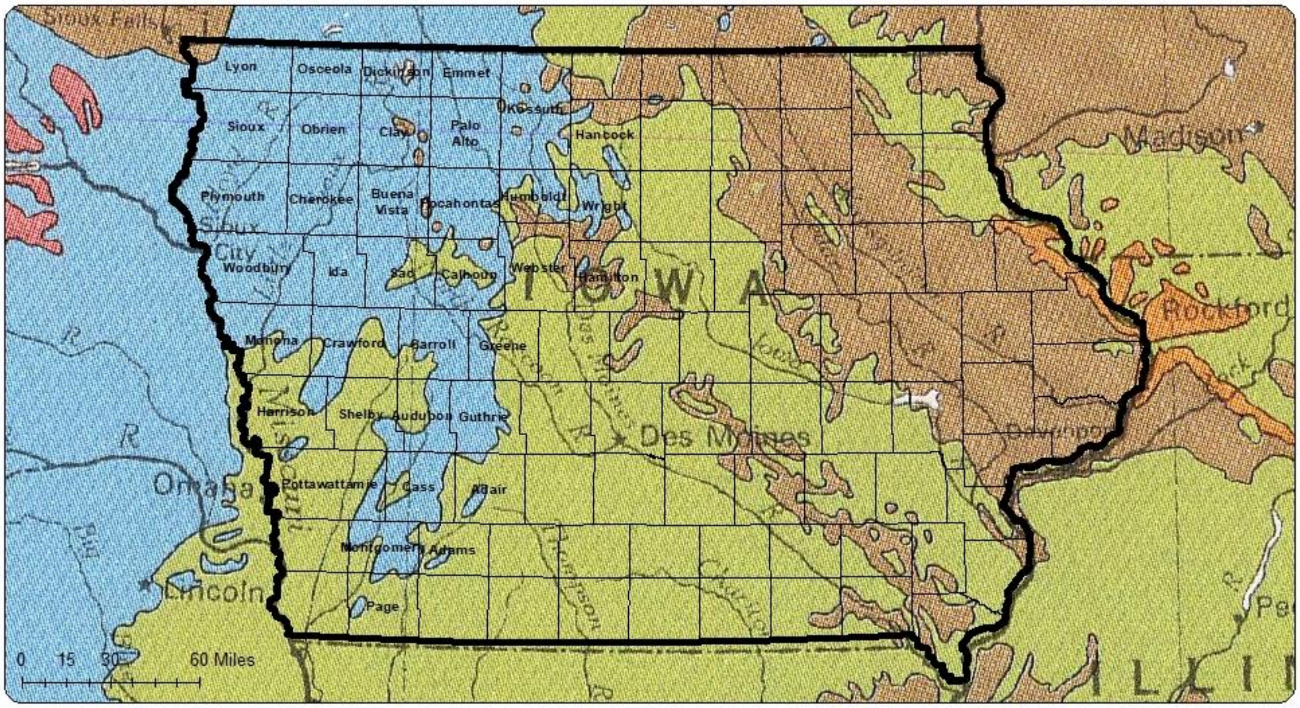
This next map shows susceptibility to earthquake damage. It illustrates that the southeast corner of Iowa has a higher probability (2% in 50 years) than the rest of the state of experiencing moderate perceived shaking from an earthquake (with very light damage expected, see Mercalli scale chart and other information in Earthquake hazard profile in section 3.3). Jurisdictions experiencing growth in southeast Iowa, therefore, may want to consider building codes and other earthquake mitigation measures for new development.

The recent growth and development areas can be contrasted to the area of one more hazard: expansive soils, otherwise known as swelling clay soils. The map below illustrates that northwest Iowa has soils with the most swelling potential. Jurisdictions in northwest area with growth and development should pay closer attention to expansive soils than those in other parts of the state.

Peak Horizontal Acceleration with 2% Probability of Exceedance in 50 Years, NEHRP site class B/C (V_{30} = 760 m/s)



Iowa Swelling Clay Soils



All data shown in this map is considered preliminary, unless otherwise noted. Neither the State of Iowa Homeland Security and Emergency Management Department, nor any of their employees, makes any warranty of representation, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefullness of any information,apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.

Projection:
NAD 1983 UTM Zone 15N
Transverse Mercator

U.S. Geological Survey
"Swelling Clays Map of the Conterminous United States"
by W. Olive, A. Chelborad, C. Frahme, J. Shlocker, R. Schneider and R. Schuster, 1989.

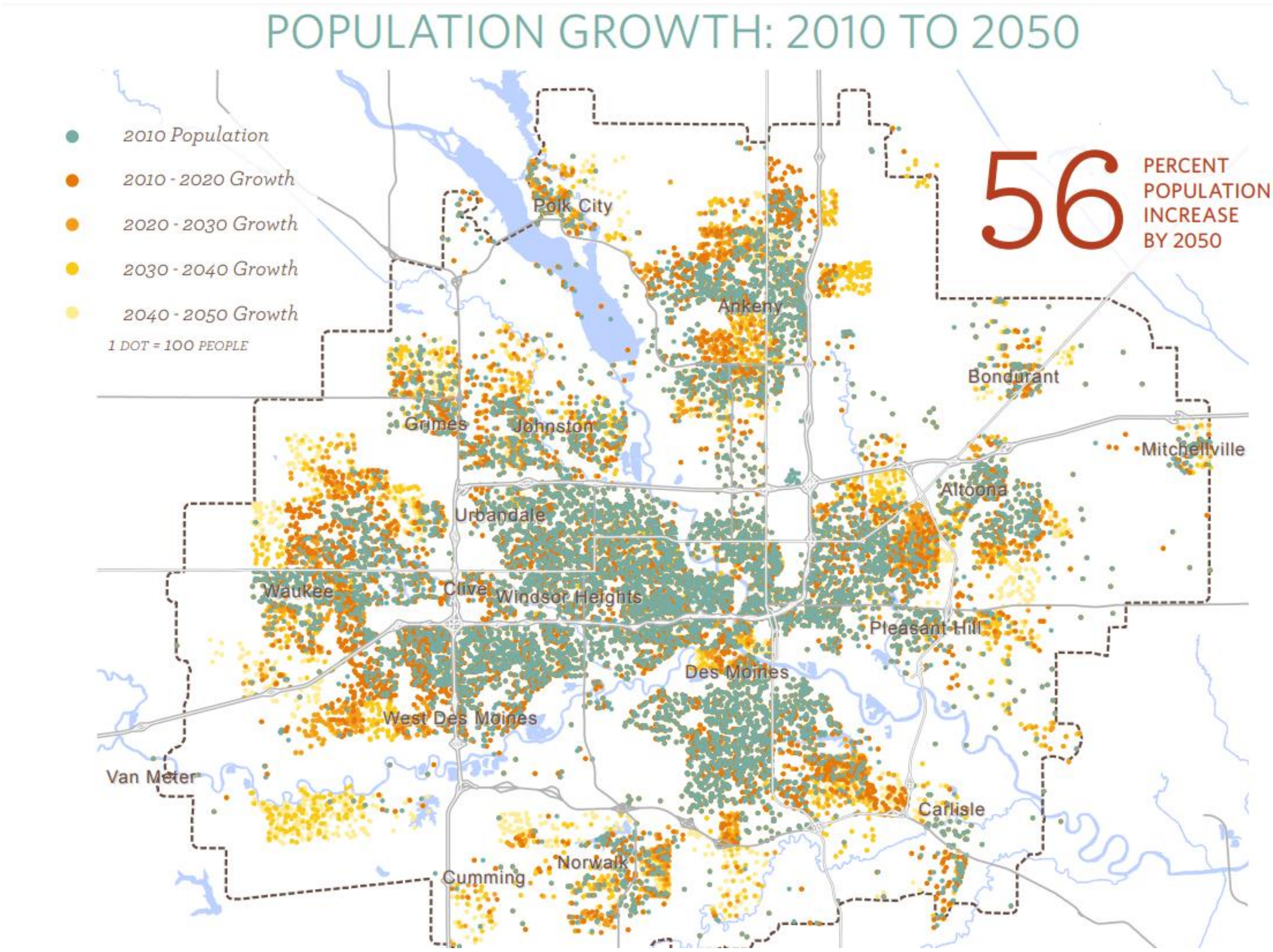
- Part of unit, generally less than 50 percent, consists of clay having high swelling potential
- Unit contains abundant clay having slight to moderate swelling potential
- Part of unit, generally less than 50 percent, consists of clay having slight to moderate swelling potential
- Unit contains little or no swelling clay

B. Projected Growth and Development

The maps above illustrate locations of recent development and growth in the state. Many of these same areas are projected to keep growing. As development pressure comes to these areas, state and local officials should consider the hazard-prone areas as illustrated in order to plan, control and/or regulate growth so that future hazard impacts can be avoided. Some of the metropolitan planning organizations (MPOs) in the state have gathered information from city plans and other sources and have used this information to create maps of potential growth and development areas. These maps are shown below.

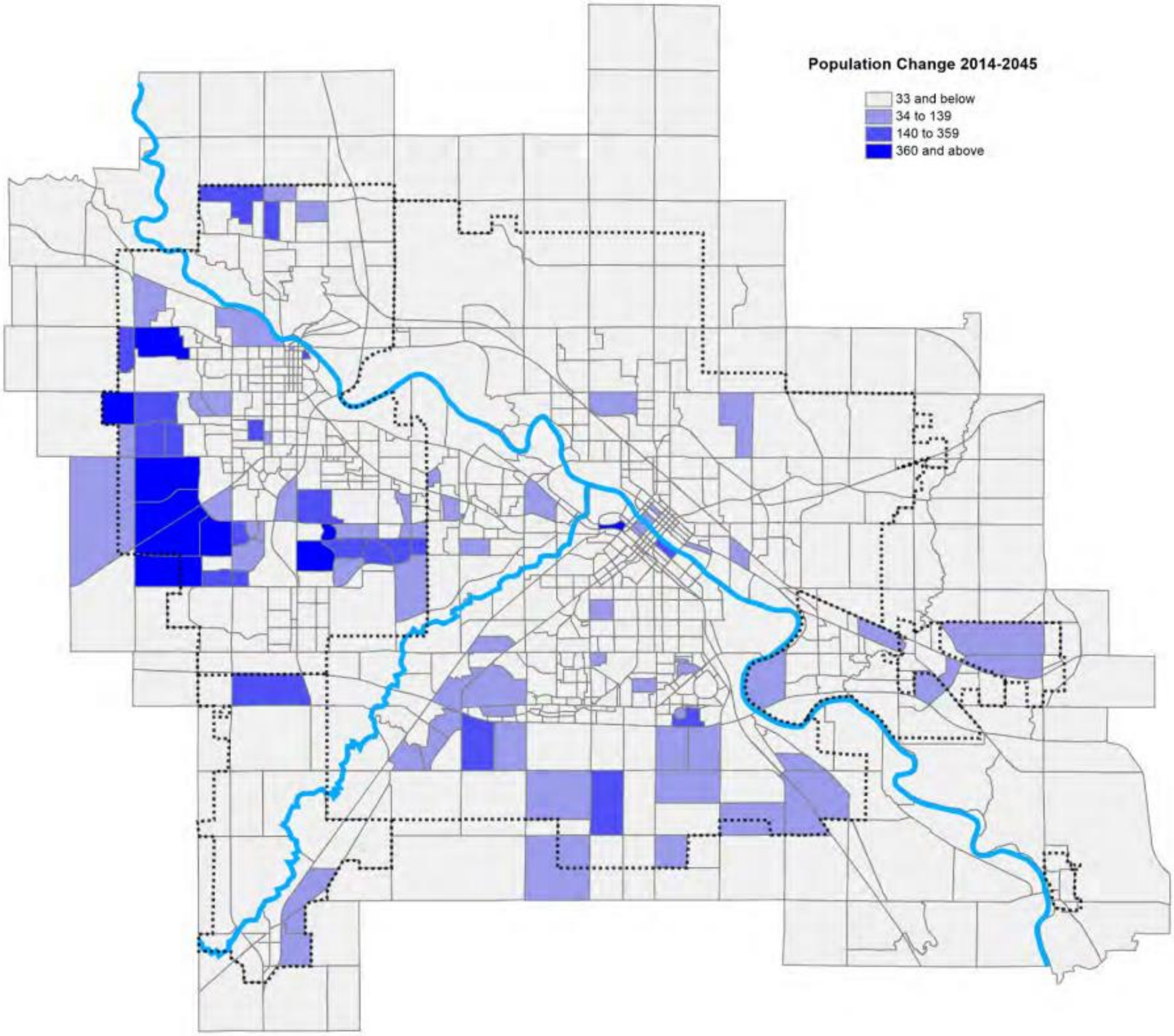
Projected Growth in the Des Moines Metropolitan Area.

Source: Des Moines MPO's long range transportation plan *Mobilizing Tomorrow*, available at https://dmampo.org/mobilizing-tomorrow/ (see Appendix C or https://dmampo.org/wp-content/uploads/2015/04/growth-scenario-report_2016.pdf)

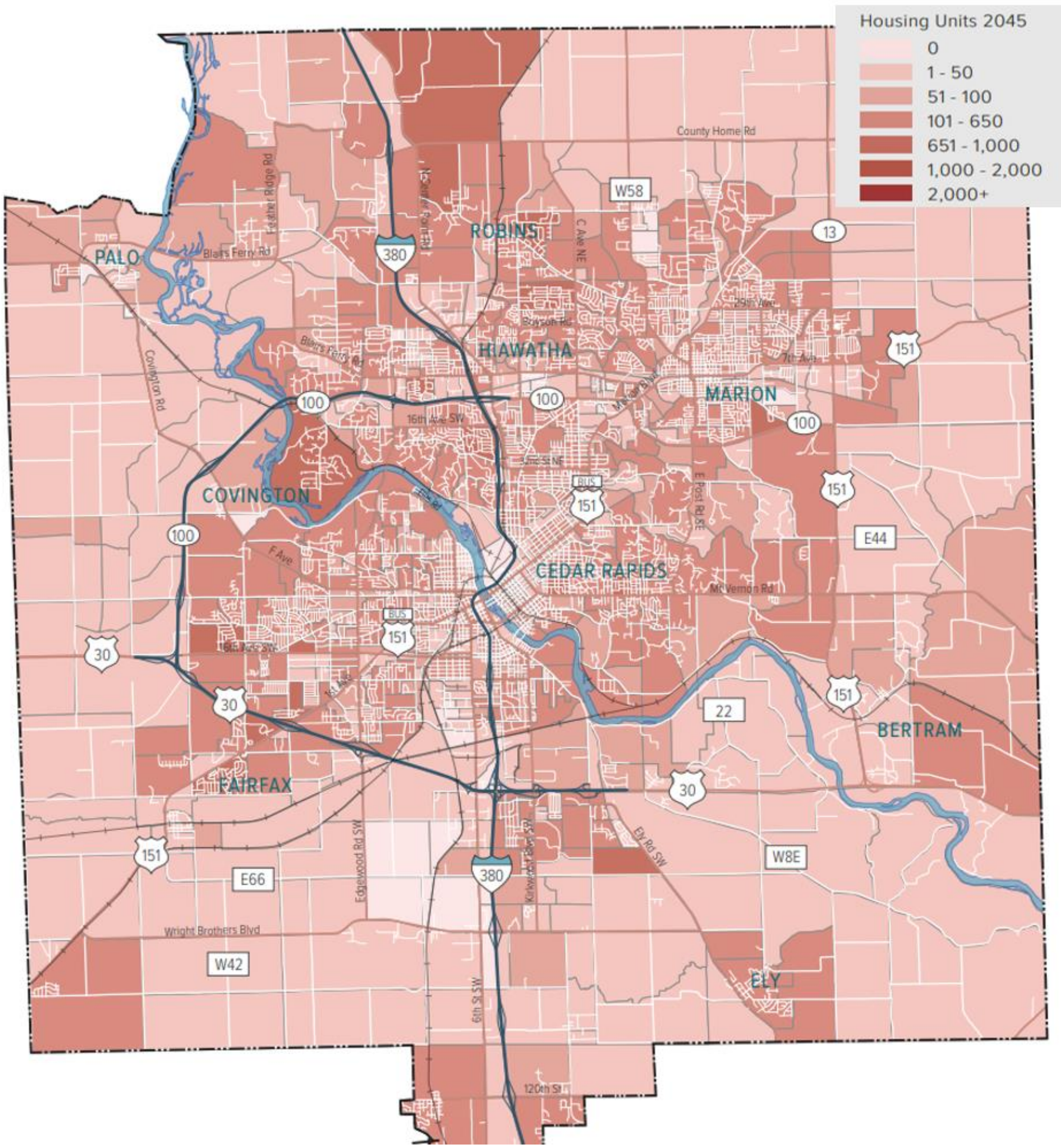


Waterloo – Cedar Falls Area Forecasted Population Change, 2014-2045

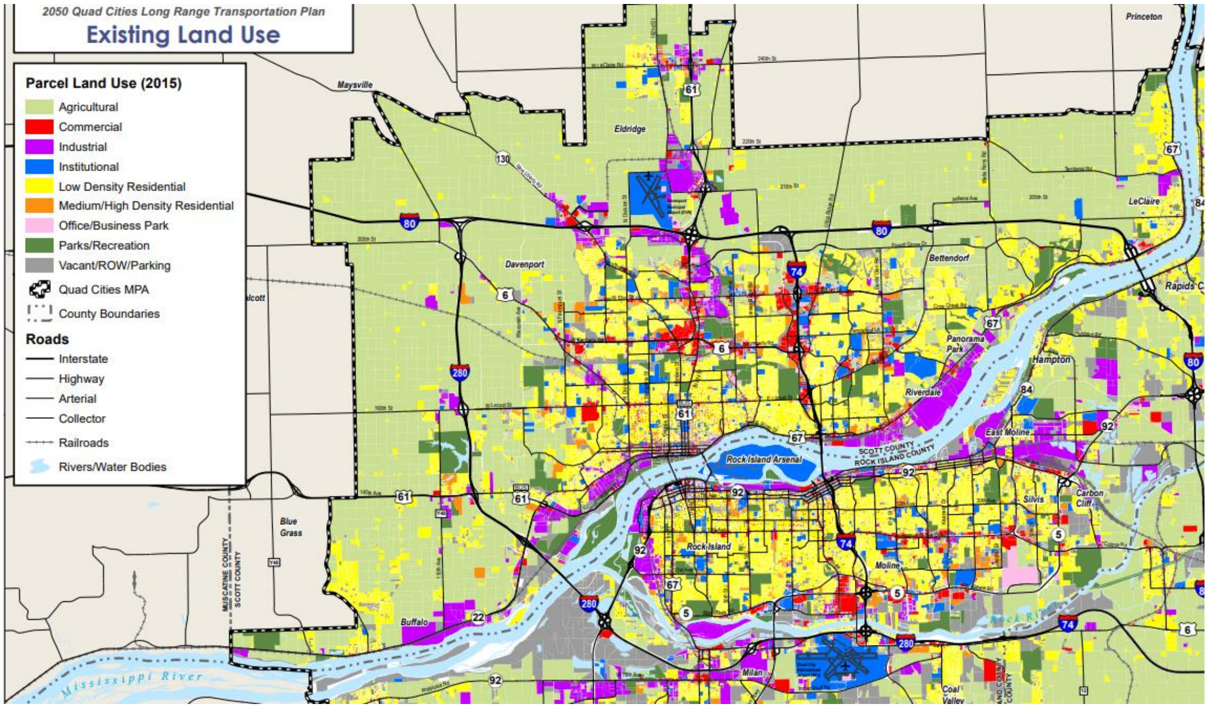
Source: Black Hawk County MPO 2045 Travel Demand Model, page 22 of Long Range Transportation Plan (http://www.inrcog.org/pdf/MPO_2045_LRTP_Chapter_2_MPO_Profile.pdf)

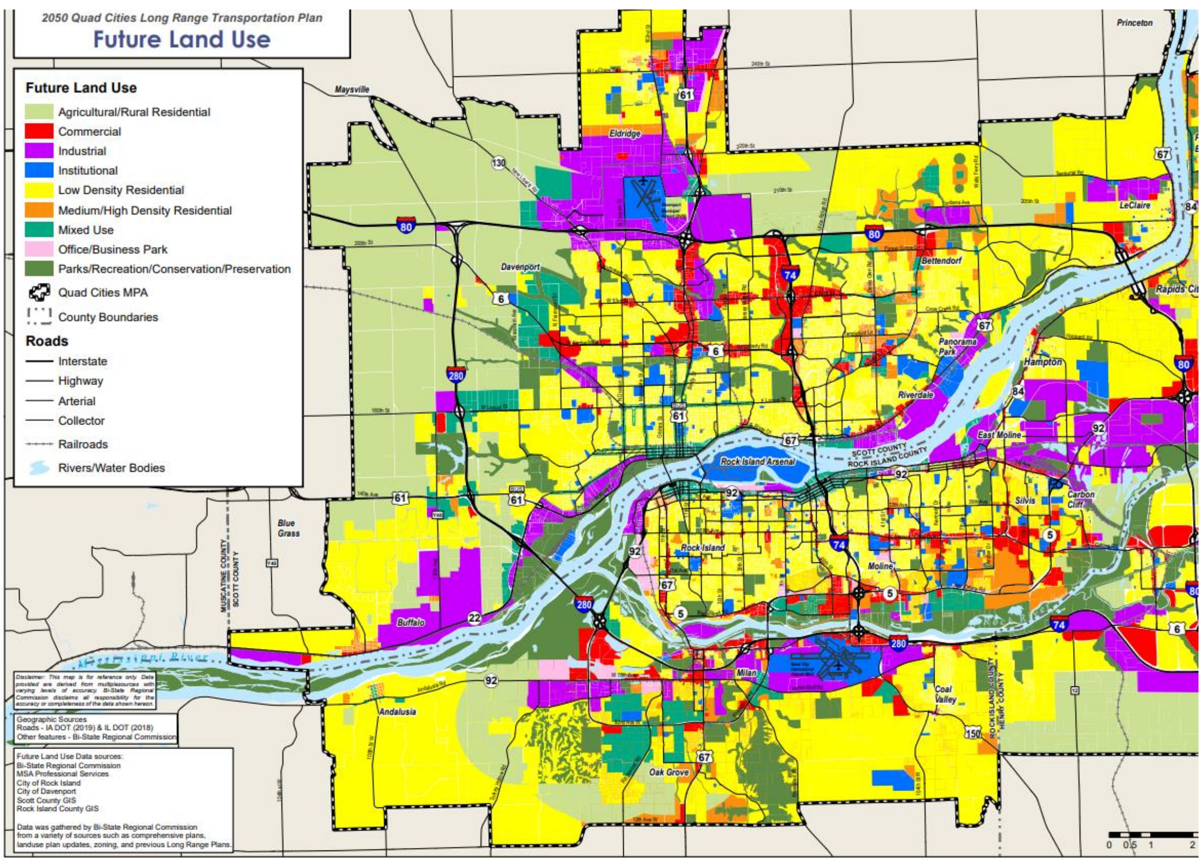


Projection of Housing Units in Cedar Rapids Area, 2045. Source: Page 24 of *Corridor 2045 Long Range Transportation Plan*



Quad Cities Projected Land Use. Source: *Connect QC 2050: Quad Cities Long Range Transportation Plan* (p. 39-40), see https://bistateonline.org/transportation/quad-cities-metro-planning/2012-11-13-20-19-45/quad-cities-metro-lrtp-long-range-transportation-plan.html





The growth and development areas shown in the above MPO maps will not necessarily come to pass as illustrated. They are based on trends, projections and plans, but do not guarantee anything. A reliable projection of immediate future growth and development comes from recent building permit data. Before builders and contractors erect new buildings, they must first acquire building permits from local governments. The US Census surveys local governments to find out how many building permits they issue. The adjacent chart shows counties where more than 100 permits have been issued recently. It indicates which counties will have near-term development and should be mindful of how hazard risk will impact these growth areas.

County	Housing Units Permitted 2020 & 2021
Polk	9365
Dallas	2636
Johnson	2060
Linn	1451
Warren	1074
Scott	861
Dubuque	814
Woodbury	801
Dickinson	583
Story	551
Black Hawk	406
Marion	372
Pottawattamie	338
Clarke	229
Muscatine	216
Cerro Gordo	216
Madison	193
Winneshiek	192
Webster	182
Jasper	162
Buena Vista	143
Mitchell	132
Washington	126
Clinton	123
Marshall	115
Boone	113
Bremer	112
Allamakee	104
Cedar	102

3.2.2. Climate change trends

44 CFR 201.4 (c) (2) (i)

FEMA's *State Mitigation Planning Policy Guide* directs that the risk assessment in the state hazard mitigation plan include "an overview of the probability of future hazard events" and that probability "must include considerations of changing future conditions, including climate change (e.g., long-term weather patterns, average temperature, and sea levels) on the type, location, and range of anticipated intensities of identified hazards."[3]

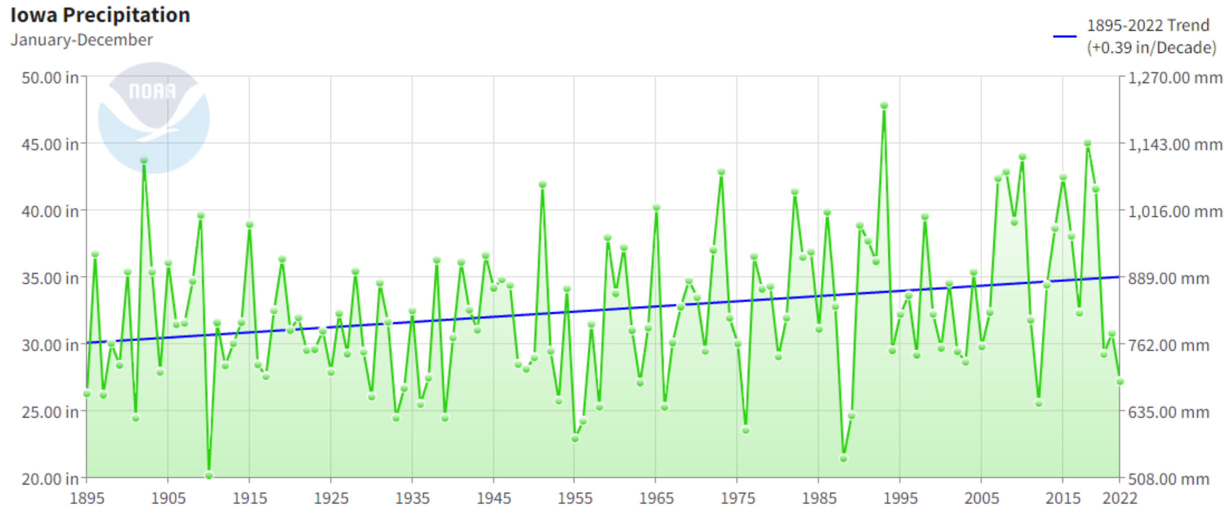
Iowa would do well to start adapting today to the future that climate trends and projections depict, which is one of more frequent and more intense natural disasters. An accurate projection will be nuanced, however, in that not all natural disasters are getting worse equally across the state, and some are not necessarily worsening at all. To prepare for and mitigate the effects of climate change on Iowa's prosperity, culture, and natural resources, planners considering future conditions should take the potential effects of climate change into account.

Trend lines for *observed* temperature, humidity, and precipitation suggest long-term increases in all three. Climate change is more than a mere increase in average temperatures. It can affect all aspects of life in Iowa, no matter one's location or lifestyle. Natural hazard risks, agriculture, outdoor recreation, cost of living, migration of plants and animals, human migration – all can be impacted. The economic impacts of climate change alone would make natural hazards more difficult to deal with. The Fourth National Climate Assessment (NCA4) notes that the southern Midwest (including part of Iowa) is projected to lose 5 to 25 percent of its current corn and over 25 percent of its

[3] FEMA, *State Mitigation Planning Policy Guide*, FP 302-094-2 (April 19, 2022), "S4" at 22.

soybean yield by 2050.[4] With agricultural production and processing industries representing 9.3% of Iowa's GDP,[5] much of which is dependent on these two crops, these projected impacts on our economy are serious.

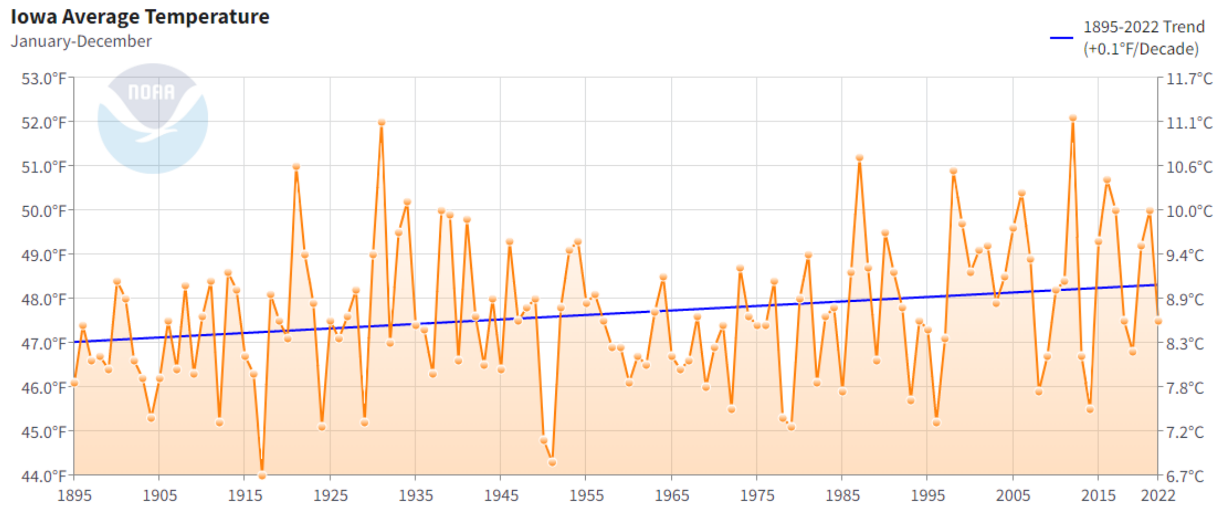
Since the beginning of the 20th century, average temperatures in Iowa have increased by over 1°F. If this trend continues, some of Iowa's natural hazards are expected to increase in frequency and intensity. The atmosphere acts like a sponge, and the warmer it is, the bigger it gets and the more moisture it can hold. Consequently, it pulls more moisture from plants and soil, but primarily in the summer when temperatures are higher.[6] The atmosphere's ability to hold more moisture also means that it takes more moisture to cause a precipitation event, which in turn means that the time between events is increased (more droughts), and the potential for high-intensity precipitation is increased (more floods).



[4] USGCRP, 2018: *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*, Chapter 21: Midwest, "Agriculture", [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, doi: 10.7930/NCA4.2018, https://nca2018.globalchange.gov/chapter/21/

[5] Division of Agriculture, University of Arkansas, Economic Impact of Agriculture: Iowa, https://economic-impact-of-ag.uada.edu/iowa/ (2020)

[6] This being said, Iowa's temperature increase thus far has been concentrated in nighttime temperatures or in winter and fall.



According to the Fourth National Climate Assessment, "As an example, for the Cedar River Basin in Iowa, the 100-year flood (1% chance of occurring in a given year) of the 20th century is projected to be a 25-year flood (4% chance per year) in the 21st century."[7] This is a meaningful increase in the amount of flooding expected in some of Iowa's most populous areas. Making this worse, transitioning between drought and flood can lead to erosion and runoff (and consequently poor water quality), harmful algal blooms,[8] and the spread of disease.[9]

According to NOAA's Annual 2021 Global Climate Report, average temperatures have already increased by about 2°F globally since 1880.[10] Warming has increased more rapidly over the past 40 years, suggesting the trend is not linear, but accelerating.[11] Although Iowa's warming has only been about 1.3°F

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[7] USGCRP, 2018: *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*, Chapter 21: Midwest, "Agriculture", [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, doi: 10.7930/NCA4.2018, https://nca2018.globalchange.gov/chapter/21/ (*citing* Anderson, C., D. Claman, and R. Mantilla, 2015: Iowa's Bridge and Highway Climate Change and Extreme Weather Vulnerability Assessment Pilot, HEPN-707, Iowa State University, Institute for Transportation, Ames, IA)

[8] NCA4, Chapter 21: Midwest, "Agriculture", https://nca2018.globalchange.gov/chapter/21/ (*citing* Loecke, T. D., A. J. Burgin, D. A. Riveros-Iregui, A. S. Ward, S. A. Thomas, C. A. Davis, and M. A. S. Clair, 2017: Weather whiplash in agricultural regions drives deterioration of water quality. *Biogeochemistry, 133 (1), 7–15. doi:10.1007/s10533-017-0315-z)*

[9] Mora C, McKenzie T, Gaw IM, Dean JM, von Hammerstein H, Knudson TA, Setter RO, Smith CZ, Webster KM, Patz JA, Franklin EC (2022) Over half of known human pathogenic diseases can be aggravated by climate change. *Nature Climate Change* https://doi.org/10.1038/s41558-022-01426-1, https://camilo-mora.github.io/Diseases/?type=,0&id=,2&impact=Negative (*citing, among others*, Duane J. Gubler, Paul Reiter, Kristie L. Ebi, Wendy Yap, Roger Nasci,and Jonathan A. Patz, 2001, Climate Variability and Change in the United States: Potential Impacts on Vector and Rodent-Borne Diseases)

[10] Climate.gov, Climate Change: Global Temperature, https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature (*citing* NOAA, Annual 2021 Global Climate Report)

[11] Climate.gov, Climate Change: Global Temperature, https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature (*citing* NOAA, Annual 2021 Global Climate Report)

in a similar timeframe (see the 1895-2022 trendline above), global averages affect the state both directly (the atmosphere is globally connected) and indirectly (economies, governments, and societies are globally connected). The 2017 U.S. Climate Science Report notes that in a higher greenhouse gas (GHG) concentration scenario, within 80 years we would likely see average global temperatures *at least* 5°F warmer than the averages of the first half of the 20th century.[12] It reports furthermore that even if the currently increasing rate of GHG concentrations begins decreasing significantly by 2050, we can expect average temperatures at least 2.4°F and as much as 5.9°F warmer. To be more cautious in projections, this plan anticipates the latter. It is not, however, the average that affects us most, but the extremes. Weather extremes have already begun to worsen, and are expected to continue.

Assuming current trends, conditions will gradually deteriorate. Significant efforts to reduce GHG concentrations can minimize that deterioration, but even in the next two decades, well within the range of local planning efforts, Iowa should plan for an increase in floods, droughts, high heat, new pests and diseases, and weakened ecosystems (see *Projected changes in Iowa over the next 20-30 years* below).

Scientists working on climate change projections struggle against the appearance of alarmism (i.e. making the problem appear worse than it is). In part as a result of trying to avoid accusations of alarmism, and in part because science should not over-state statistical outliers, scientists have also been accused of *understating* the potential dangers of climate change. When assessing and mitigating natural hazard risks from climate change, it can be similarly difficult to walk the line between preparing against real dangers and preparing for less likely, but more dangerous possibilities. Yet the differences between higher and lower GHG-concentration scenarios require significantly different levels of resilience.

Iowa would ideally be prepared for the worst-case scenario, but with limited resources, mitigation activities will have to focus on the most likely scenarios, rather than the most dangerous. Likelihood of future GHG concentrations levels is hard to predict, as is the exact outcome in the future climate. Existing resource limitations require prioritizing the most vulnerable sites or populations. With or without climate change, the sites in Iowa most at-risk of natural disasters (e.g., flood-prone areas, aging infrastructure, vulnerable populations, or communities with limited water resources) will continue to be the priority for hazard mitigation. For instance, even as new land may be placed in special flood hazard areas (SFHAs) due to increased precipitation extremes, the lowest-lying areas already in SFHAs will likely continue to be more at-risk than those newly added.

Still, some conditions are very likely to change, and it will be prudent to prepare for worsening conditions. Iowa already experiences heatwaves, for example, but we should prepare for them to occur more often. Some communities not currently prone to emergencies such as heat will likely become at-risk, and some of these will not have the local capacity to mitigate these new hazards. Communities not currently vulnerable may also become vulnerable as climate change and social change affect local economies and demographics.

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[12] Climate.gov, Climate Change: Global Temperature, https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature (*citing* USGCRP, 2017: *Climate Science Special Report: Fourth National Climate Assessment, Volume I* [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. U.S. Global Change Research Program, Washington, DC,

In coastal areas, the term 'managed retreat' refers to the abandonment of areas being lost to sea-level rise. While perhaps on a smaller scale, Iowa has also been executing a managed retreat from flood-prone areas through acquisitions and demolitions (also known as 'buyouts'). As the cost of rebuilding and protecting structures and facilities in these areas increases, it becomes more cost-effective to instead move further from rivers, lakes, and streams or low-lying areas. Even existing flood protection such as levees may become cost-effective to abandon or move rather than rebuild if the value of the assets they protect has decreased since construction or as the likelihood of levee damage or overtopping increases with climate change.

At the same time, other hazards may decrease with climate change. Extreme cold and winter storms may come less frequently as winters warm, though they may not disappear entirely.[13] Likewise, tornadoes, a source of many disasters in Iowa, do not appear to be increasing with climate change.[14] That said, the spatial distribution of tornado occurrences appears to have moved eastward in the past 40 years, with most of Iowa seeing more days *favorable* to tornado formation, and there has been some variation in when tornadoes happen.[15] Since these changes have not been tied to climate change per se, it is unclear whether or how long the trends will continue. Nevertheless, warming winters will likely extend tornado season.

Changes to Iowa's environment should not be expected to occur all at once, but have been steadily advancing. At some points, the impacts of climate change on Iowa may even be beneficial (e.g., crop productivity from increased CO_2 in the atmosphere). As climate change continues into the mid- to late 21st century, however, NCA4 projects generally negative overall effects on agriculture, forestry, ecosystems, human health, transportation, and infrastructure.

A. Climate changes to date in Iowa

The following observations regarding recent changes in Iowa's climate are noted on the Iowa DNR's website (not including sub-points, except as noted).

- Increased humidity, especially in summer, fueling thunderstorms[16]
  - Every 1°F increase in atmospheric temperature allows the atmosphere to hold 4% more water vapor
- Higher temperatures[17]
  - Warmer nighttime temperatures (DNR)
  - Winters warming six times faster than summers (DNR)
- Increased precipitation (8 percent from 1873 to 2008)[18]

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[13] The 'polar vortex' above the arctic, for instance, may or may not bring more frigid air into Iowa as climate change shifts arctic weather patterns and melts sea ice. *See* R. Lindsey, Understanding the Polar Vortex, https://www.climate.gov/news-features/understanding-climate/understanding-arctic-polar-vortex (March 5, 2021).
[14] Bob Henson, Yale Climate Connections, "Climate change and tornadoes: Any connection?" https://yaleclimateconnections.org/2021/07/climate-change-and-tornadoes-any-connection/ (July 19, 2021).
[15] *Id*.
[16] Iowa DNR, Climate Change, https://www.iowadnr.gov/Conservation/Climate-Change
[17] Iowa DNR, Climate Change, https://www.iowadnr.gov/Conservation/Climate-Change
[18] Iowa DNR, Climate Change, https://www.iowadnr.gov/Conservation/Climate-Change. Notably, NOAA reports a 5-inch change for Iowa from 1895 to 2022, from about 30 to about 35 inches on average per year. This represents

- Wetter winter, spring and fall, but occasionally dryer summers, with the exception of northeast Iowa, which is now wetter in all seasons[19]
- Precipitation extremes (less frequent but more intense), leading to soil erosion and flooding (DNR)
- A higher increase in eastern Iowa than in western Iowa (DNR)

- Abnormal seasons
  - Longer average growing season by two weeks (frost-free seasons increased by an average of nine days since 1901)[20]
  - Longer pollen season, exacerbating allergies, asthma, and sinusitis[21]
  - Plants leafing out and flowering sooner
    - Migrating pollinators miss plants that bloom too early, endangering both
  - Birds migrating earlier, sometimes missing seasonal waters and food sources
- Habitable ranges changing (some native plants and animals having a harder time in Iowa, some from warmer regions moving north)
- Favorable conditions for survival and spread of many unwanted pests and pathogens[22]
- Lower air quality
  - Higher temperatures, sun, and stagnant air are generally more favorable to ozone formation. Rain, wind, humidity, clouds, and cool air limit ozone formation.[23]
  - High ozone concentrations, which can be high in both rural and urban contexts may reduce soybean and corn yields by 5 and 10 percent, respectively.[24] Ozone also negatively impacts human and animal health.
- Although not in Iowa, acidifying and warming oceans are contributing to mass loss of ocean life and biodiversity, hampering the health of the oceans that feed millions of humans.[25] Iowa's cold-water fish would face difficulties in a warming climate as well.[26]

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closer to a 17 percent change. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/statewide/time-series/13/pcp/ann/7/1895-2022?trend=true&trend_base=10&begtrendyear=1895&endtrendyear=2022

[19] NOAA, U.S. Climate Normals, "Normals Comparison Maps" https://www.ncei.noaa.gov/products/land-based-station/us-climate-normals

[20] USGCRP, *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*, Chapter 21: Midwest, [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, doi: 10.7930/NCA4.2018, https://nca2018.globalchange.gov/chapter/21/ (2018).

[21] *Id.*

[22] Iowa DNR, Climate Change, https://www.iowadnr.gov/Conservation/Climate-Change

[23] U.S. EPA, Trends in Ozone Adjusted for Weather Conditions, https://www.epa.gov/air-trends/trends-ozone-adjusted-weather-conditions (June 1, 2022)

[24] Justin M. McGrath, Amy M. Betzelberger, Shaowen Wang, Eric Shook, Xin-Guang Zhu, Stephen P. Long, & Elizabeth A. Ainsworth, An analysis of ozone damage to historical maize and soybean yields in the United States, *Proceedings of the National Academy of Sciences*, *112*(46), November 2, 2015. https://www.pnas.org/doi/abs/10.1073/pnas.1509777112

[25] USGCRP, *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*, Chapter 9: Oceans and Marine Resources, "Ocean Ecosystems", U.S. Global Change Research Program, Washington, DC, USA, doi: 10.7930/NCA4.2018, https://nca2018.globalchange.gov/chapter/9/ (2018).

[26] USGCRP, *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*, Chapter 21: Midwest, [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock,

B. Projected changes in Iowa over the next 20-30 years

These projections come from the NCA4, unless otherwise noted.

- More of the effects already seen, magnified as temperatures rise
- Annual average temperatures at least 2.4°F higher compared to the first half of the 20th century, according to NOAA[27]
- Increased heat waves
    - By 2050, most of Iowa is projected to see about one extra month per year of daily high temperatures above 90°F than was observed from 1961 to 1990, according to the U.S. Climate Resilience Toolkit.[28] Lower numbers are under the RCP 4.5 scenario; higher numbers are under the RCP 8.5 scenario.
        - Lyon (NW): 33 to 37 more days (49 to 53 days total)
        - Allamakee (NE): 20 to 31 more days (26 to 37 days total)
        - Story (Central): 29 to 38 more days (42 to 51 days total)
        - Fremont (SW): 36 to 48 more days (66 to 78 days total)
        - Lee (SE): 34 to 44 more days (52 to 62 days total)
    - Heat stress affects both urban and rural populations, especially those without air conditioning. Livestock are also vulnerable to heat stress.
- Increased humidity
    - Leads to increased spring rainfall, soil erosion, and fewer planting-season work days[29]
- Lower air quality
    - Warmer temperatures lead to higher surface-level ozone. NCA4 notes that higher ozone levels could lead to 200 to 550 more premature deaths annually across the Midwest by 2050.[30] Livestock are also vulnerable to higher ozone levels.
- Frost-free seasons increasing by up to 10 days by 2045 and 20 days by 2065, compared to the period of 1976-2005, according to NCA4 (these numbers are projections under the RCP 8.5 scenario)[31]
- Increased spread of some diseases
- Increased heavy precipitation and flooding events
- Increased drought
    - With warmer air, the atmosphere pulls more moisture from plants, leading to increased tree mortality and stressed crops.[32]
- Loss of plant and animal habitat and ecosystems in flux
- Invasion by non-native species and tropical pests and diseases

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and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, doi: 10.7930/NCA4.2018, https://nca2018.globalchange.gov/chapter/21/ (2018).

[27] Climate.gov, Climate Change: Global Temperature, https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature (*citing* NOAA, Annual 2021 Global Climate Report)

[28] U.S. Federal Government, U.S. Climate Resilience Toolkit Climate Explorer, https://crt-climate-explorer.nemac.org/climate_maps/?id=tmax (2021). Note: rounding may lead to discrepancies of up to 1 day.

[29] NCA4, Chapter 21: Midwest, "Agriculture", https://nca2018.globalchange.gov/chapter/21/

[30] NCA4, Chapter 21: Midwest, "Agriculture", https://nca2018.globalchange.gov/chapter/21/

[31] NCA4, Chapter 21: Midwest, "Agriculture", https://nca2018.globalchange.gov/chapter/21/

[32] NCA4, Chapter 21: Midwest, "Agriculture", https://nca2018.globalchange.gov/chapter/21/

- Decreased corn yields due to heat stress, despite longer growing season and higher CO_2
- *Increased* soybean yield due to higher CO_2, though potentially less so in southern Iowa
- Drought, decreased snowpack, and early spring melts may lead to low summer streamflows at times when high heat will drive demand for water.

C. Expected Changes in Iowa by 2100

- More of the effects already seen, magnified as temperatures rise
- More extreme heat waves
  - By 2100, most of Iowa is projected to see about six weeks more per year above 90°F than was observed from 1961 to 1990, according to the U.S. Climate Resilience Toolkit.[33] In some areas, there may be nearly four months of these hot days. Lower numbers are under the RCP 4.5 scenario; higher numbers are under the RCP 8.5 scenario.[34]
    - Lyon (NW): 40 to 76 more days (56 to 92 days total)
    - Allamakee (NE): 36 to 69 more days (42 to 75 days total)
    - Story (Central): 41 to 80 more days (54 to 93 days total)
    - Fremont (SW): 47 to 84 more days (77 to 114 days total)
    - Lee (SE): 48 to 86 more days (66 to 104 days total)
  - By 2100, Iowa is projected to see at least a tenfold increase in days per year above 100°F than was observed from 1961 to 1990.[35] With higher GHG concentrations, the increase in some counties may be closer to a hundredfold, with some seeing several weeks over 100°F per year. Lower numbers are under the RCP 4.5 scenario; higher numbers are under the RCP 8.5 scenario.
    - Lyon (NW): 8 to 35 more days (9 to 35 days total)
    - Allamakee (NE): 4 to 21 more days (4 to 21 days total)
    - Story (Central): 7 to 32 more days (7 to 32 days total)
    - Fremont (SW): 16 to 52 more days (17 to 53 days total)
    - Lee (SE): 11 to 38 more days (12 to 38 days total)
- Decreased soybean yield due to heat stress, despite higher CO_2, according to NCA4.
- Frost-free seasons increasing by 30 days compared to the period of 1976-2005, according to NCA4.

D. Hazard-by-Hazard Expected Conditions

Hazard	Expected changes
Drought	Varies regionally. May be more common in northwestern and southern counties. Northeastern counties, while potentially experiencing a greater increase in precipitation than the rest of the state, may be affected by drought more often than they are now. Precipitation could be expected to vary more both temporally and spatially, with one area experiencing record heat and drought while nearby areas experience heavy precipitation. Drought may take on a seasonal aspect, with excessive moisture in spring and insufficient moisture in summer. Iowa already sees wetter spring and fall and dryer summers than in its previous climate decade. Higher temperatures will increase evaporation rates, intensifying naturally-occurring droughts.

[33] U.S. Federal Government, U.S. Climate Resilience Toolkit Climate Explorer, https://crt-climate-explorer.nemac.org/climate_maps/?id=tmax (2021). Note: rounding may lead to discrepancies of up to 1 day.
[34] See section below for explanation of RCP scenarios.
[35] *Id.*

Hazard	Expected changes
Tornado/ Windstorm	Uncertain. Frequency and intensity do not appear to be changing. Some evidence suggests that 'Tornado Alley' – an area most favorable to tornado formation – is moving east, but the biggest effect of this is in the South. The likelihood of a tornado in any given part of Iowa has not significantly shifted. As temperatures rise, however, the length of tornado season may increase.
Flooding (Flash & Riverine)	Increasing. Precipitation is expected to increase in intensity, though not necessarily frequency. With average annual precipitation increasing only 1" to 4" in any county by 2050, however, heavy precipitation events are likely to become more common. Eastern Iowa seeing higher increase in precipitation than western Iowa indicates greater likelihood of flooding in eastern Iowa.
Severe Winter Storms	Decreasing. As winters warm faster than summers, winter weather is expected to cause less damage in coming decades. Overnight lows are increasing quickly relative to daytime temperatures, meaning there may be less than historical rates of re-freezing of snow and ice at some points in winter, and more at other points. Winters are becoming shorter as well.
Lightning and Hail Storms	Increasing. Warming summers and higher quantities of water in the atmosphere will likely fuel increased thunderstorm development.
Excessive Heat	Increasing. Days with maximum temperatures above 90 are projected to occur 2 to 5 times more often by 2050 in the best case scenario. Days above 100, currently occurring once every few years in most of Iowa, are projected to happen several times per year by 2050. Days over 105 may not be rare either. 'Cooling degree days' will nearly double in about 50 years, straining energy systems and increasing chances of blackouts and brownouts (barring adaptation measures).
Dam/Levee Failure	Increasing. Flooding is expected to increase, increasing strain on levees and likelihood of failure or overtopping. Drought is also expected to increase, which may cause levees, especially those containing clay, to crack. Heavy precipitation events following these dry spells (a cycle expected to increase with climate change) can worsen the cracks. Dams most likely to experience increase risk of overtopping, rather than catastrophic failure, but flooding strains the structure as well.
Landslide	Uncertain. Landslide damage is not centrally recorded in Iowa and has not been an impactful hazard, historically. With increasing heavy precipitation events, landslides may become more common, but resulting damage is uncertain.
Earthquake	No change expected.
Wildfire and Grass Fire	Increasing. If droughts become more common or more intense, even seasonally, dry vegetation will be more prone to ignition. High temperatures will also pull moisture from vegetation. Wind is not expected to increase.
Sinkholes	Uncertain. Sinkholes in central Iowa are general related to abandoned coal mines. Sinkholes in northeastern Iowa are generally related to the karst landscapes prevalent there. Increased precipitation could conceivably speed the dissolution of soluble rocks, and drought could conceivably lead to subsidence from loss (or over-pumping) of groundwater, but no definite projections are available. The freeze-thaw cycle can break up the ground and lead to sinkholes. Dry soil freezes faster and deeper than moist soil, so water acts as a barrier to freezing. With warming winters and wetter springs projected, the coinciding timing of each may or may not intensify the effects from the freeze-thaw cycle.
Expansive Soils	Uncertain. The expected increase in the back and forth between heavy precipitation and drought could conceivably lead to more damage, but no research in the US was readily available to support this.

E. Projections and Probability

The Fourth National Climate Assessment (NCA4) analyzes the effects of two scenarios: one in which GHG concentrations continue to rise and temperatures rise by 5.8 to 9.7°F by the end of the century (known as Representative Concentration Pathway (RCP) 8.5), and one in which GHG concentrations are significantly reduced by midcentury and warming is limited to 3.1 to 5.8°F at the end of the century (known as RCP4.5). NCA4 suggests that a lower GHG concentration scenario (e.g., RCP 1.9 or 2.6) would require significant and immediate reductions in carbon and methane concentrations. The lower end of this range still carries with it the effects of climate change already seen, but likely more severe. The higher end of this range could lead to a series of catastrophes hard to imagine. We will not likely see either extreme, but rather somewhere in the middle (an intermediate or mid-high GHG concentration scenario, such as RCP 4.5 or 6.0, respectively). Still, a mid-range temperature increase would result in a very different world than what existed in the 20th century, including more frequent and intense natural disasters and fragile, fluctuating ecosystems and agriculture.

Consideration of 'human-caused' global warming prediction scenarios is important for hazard mitigation planning in that it affects which scenarios the state should consider likely. This prediction is, on one hand, easier because we know which factors of global warming can be changed (namely, human activities), and harder because we do not know exactly how humans will behave. If current behavior is an accurate indication, a rapid decrease in human-caused GHG emissions is not likely to occur in the next decade. These emissions should be distinguished from natural emissions (e.g., volcanic activity, biological processes, or oceanic outgassing), which have been in relative equilibrium with natural GHG sinks, keeping CO_2 concentrations below 300 ppm for hundreds of thousands of years.[36] Natural sinks such as oceans and forests are not likely to increase their GHG absorption rates in the near future, nor are natural emissions likely to decrease enough to counterbalance human-caused emissions. A low GHG concentration scenario such as RCP 2.6 thus appears unlikely. With efforts underway to reduce human-caused GHG emissions, barring a sudden increase in natural emissions, a high GHG concentration scenario such as RCP 8.5 also seems unlikely. Feedback loops such as methane emissions from melting permafrost, tree mortality, or loss of solar heat reflection due to melting snow and ice sheets, are not fully understood and may cause changes outside expectations, but RCP 4.5 and RCP 6.0 have been described as likely scenarios.[37]

While plenty of climate impacts within Iowa could make the state more vulnerable to natural hazards (e.g. floods and droughts), impacts outside the state might also be seen second-hand here. Satellite imagery has shown glaciers and polar ice caps retreating for decades. Just how much will melt is unclear, but there is a potential for a significant percentage of our polar ice to melt. Additionally, as the ocean warms, it expands, increasing its size relative to landmasses and thus raising sea levels. Relatively small amounts of sea level rise (e.g., a couple feet) can lead to coastal flooding and worsening storm surges. These disasters displace people both within and outside the United States, and many may move to inland states like Iowa.

The deteriorating health of a warming and acidifying ocean will likely cause disruptions in seafood supply chains, making the demand for other foods higher as well. Land-based food sources are projected to be disrupted by crop failures within and outside Iowa, as other countries and states experience drought, flooding, pests, wildfires, and land loss due to coastal flooding or urbanization of agricultural land due to

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[36] Climate.gov, Climate Change: Atmospheric Carbon Dioxide (June 23, 2022), https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide.

[37] Zeke Hausfather & Glen P. Peters, Emissions – the 'business as usual' story is misleading', *Nature* (January 29, 2020), https://www.nature.com/articles/d41586-020-00177-3

retreats from coastal areas. People living in places most affected by climate change will likely avoid the hazards by leaving, causing a general human migration away from the coasts and equator. This could cause housing shortages in areas less affected and would disrupt economies, potentially including Iowa. Climate-induced scarcity (of water, arable land, safe weather, and other resources) can also lead to conflicts, exacerbating issues caused by migration. Similarly, the 2022 Russian invasion of Ukraine exposed and exacerbated a global food crisis that some say was caused in part by climate change.[38] Food production is a great part of Iowa's culture and economy, and as climate change threatens our agricultural sector, it could threaten our way of life. A resilient agricultural sector, conversely, could help buoy Iowa through the coming storm.

F. Summary of Climate Change in Iowa

Iowa is not unfamiliar with flooding or intense summer heat or drought. These are hazards the state is currently working to mitigate. However, it would be *terra incognita* to deal with these hazards at the projected increased rate and intensity while simultaneously dealing with a more fragile economy; supply chain shortages; incoming climate refugees and the resultant housing shortage and strain on infrastructure; crop failures; more strain on health resources due to new pests and diseases, ozone pollution, or excessive heat; and dysfunctional ecosystems that may not support native or migratory animals or plants.

A significant barrier to mitigating climate change is the fact that it moves so slowly. The more disastrous impacts are only just becoming visible. It is difficult for the human mind to comprehend a threat as vast as climate change and adequately respond to it when it always seems so far off, or so big that it would be impossible to stop. Still, there are distinct impacts that Iowa can mitigate.

The burden of preventing, preparing for, and responding to climate change and its impacts is shared across the planet and across time, but future generations bear the brunt of responding to the disasters to come. As a matter of equity, it is vital that Iowans today do justice to future Iowans and to the ecosystems that sustain us. Given the current and expected impacts listed above, mitigating climate change and its impacts is of vital importance.

3.3. Risk and Vulnerability - Hazard by Hazard

This section includes profiles of the natural hazards which Iowa faces. Natural hazards are those in which damage, harm or difficulty is created by a meteorological, environmental, or geological phenomenon or combination of phenomena"[39]. Biological and man-made hazards are addressed in the following section.

For each of the natural hazards, previous occurrences are presented followed by an assessment of the likelihood and extent of the hazard wherever it is found in Iowa. The profile of each natural hazard concludes with a summary of vulnerability and possible ways in which to address vulnerability or lessen risk.

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[38] World Economic Forum, *Global Food Crisis Must be Solved Alongside Climate Crisis* (May 24, 2022), https://www.weforum.org/press/2022/05/global-food-crisis-must-be-solved-alongside-climate-crisis
[39] *U.S. Department of Homeland Security Risk Lexicon*, 2010

3.3.1. Drought

A. General Description

Drought is defined as a period of prolonged abnormally-low precipitation producing severe dry conditions. But, what is "abnormally-low precipitation" or "severe dry conditions"? And, how long is "prolonged"? The National Drought Mitigation Center, in partnership with several federal agencies, tracks drought conditions throughout the country with the US Drought Monitor (USDM). The USDM uses several criteria to determine how severe drought is in any particular area. It updates the classifications of areas every week. Thus, the USDM has become a useful tool of tracking how severe drought is in any given area, and for how long.

The chart below illustrates the classification or categories of severity of drought that the USDM provides on a weekly basis.

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

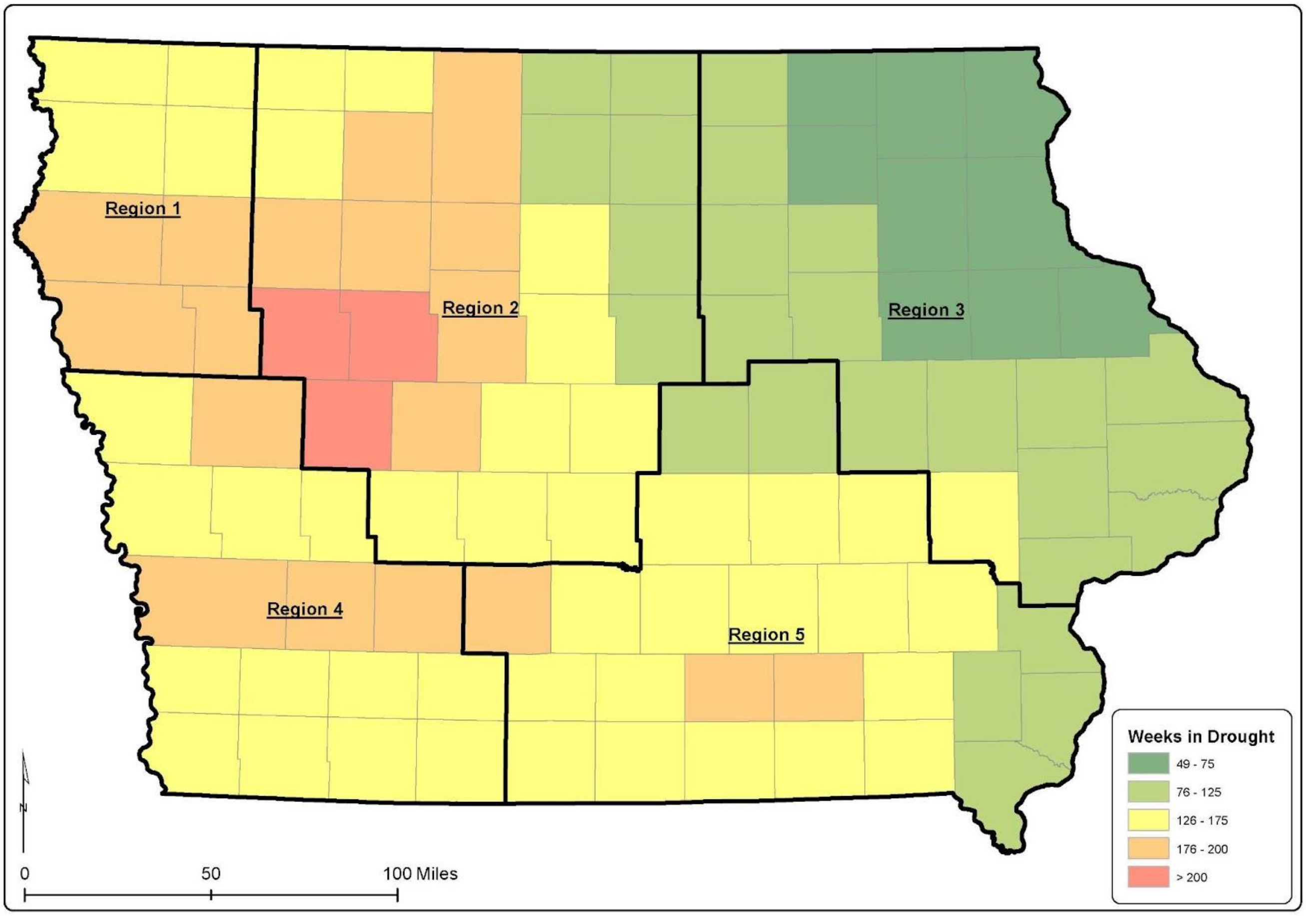
Source: National Drought Mitigation Center [Drought Classification | U.S. Drought Monitor (unl.edu)]

The USDM was created in 1999 and drought records using the USDM classifications are available since 2000. Iowa's experience with drought is examined below based on the USDM records.

B. Previous Occurrences

The map below shows counties in Iowa color-coded by how many weeks of severe drought each county has experienced from 2000 to 2022, according to the USDM. The counties with the highest number of weeks in severe drought include Carroll, Calhoun, and Sac. The northeast corner of the state shows the fewest drought weeks, while the western portion of the state shows the most, especially in the northwestern quadrant.

Non-consecutive weeks in Severe Drought (D2) or worse, 2000 - 2022



The map also shows the regions into which the recently completed state’s drought plan has divided Iowa. The state was divided into five drought zones based, in part, on landform regions. The landform regions largely reflect the diversity of geologic landscapes shaped by Quaternary age glacial deposition and post-glacial erosion over the last two million years or so. The different landform regions have similar topography, soils, geology and hydrology that make them appropriate for classifying drought regions in the state. The landform regions are irregular boundaries but the drought regions follow county boundaries for better state administration. More details on previous drought episodes are described below for each of the regions.

The average amount of the area in Region 1 in various levels of drought or dryness over the period 2000 to 2022 is 36.3% in D0, 20.1% in D1, 11.3% in D2, 3.9% in D3, and 0.4% in D4. Put another way, on any given week, one might expect about 12% of the region to be in severe drought or worse. The region has seen D4 drought during 33 weeks since 2000 (2.8% of all weeks), with an average of 15% of the region in D4 drought during those times.

The average amount of the area in Region 2 in various levels of drought or dryness over the period 2000 to 2022 is 36.0% in D0, 20.3% in D1, 10.1% in D2, 2.8% in D3, and 0% in D4. Put another way, on any given week, one might expect about 10% of the region to be in severe drought or worse. D4 drought has never been seen in Region 2 since the USDM's inception in 2000.

The average amount of the area in Region 3 in various levels of drought or dryness over the period 2000 to 2022 is 25.4% in D0, 13.0% in D1, 5.0% in D2, 1.5% in D3, and 0% in D4. Put another way, on any given week, one might expect about 5% of the region to be in severe drought or worse. D4 drought has never been seen in Region 3 since the USDM's inception in 2000.

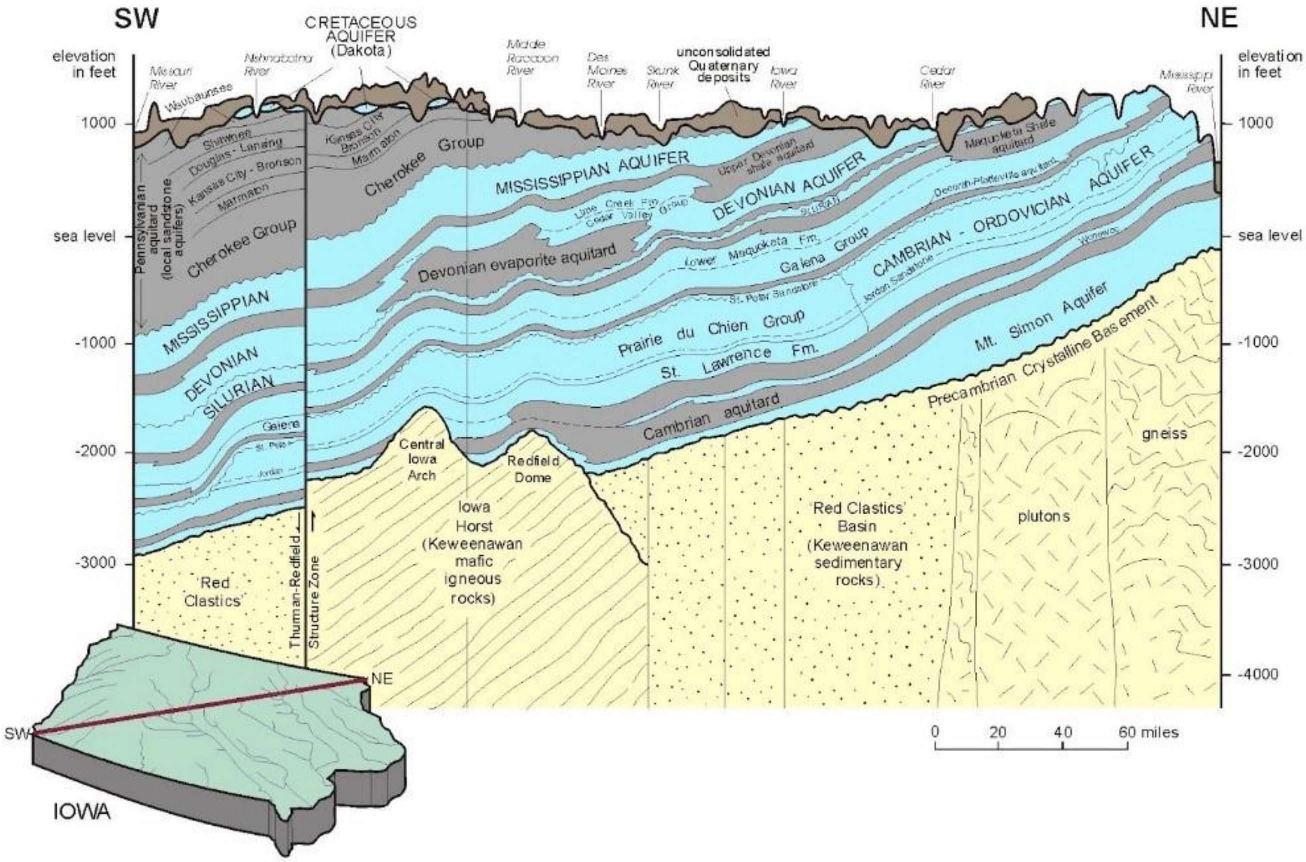
The average amount of the area in Region 4 in various levels of drought or dryness over the period 2000 to 2022 is 38.3% in D0, 21.4% in D1, 9.6% in D2, 2.0% in D3, and 0% in D4. Put another way, on any given week, one might expect about 12% of the region to be in severe drought or worse. Only 14 weeks have seen D4 drought in Region 4 since 2000.

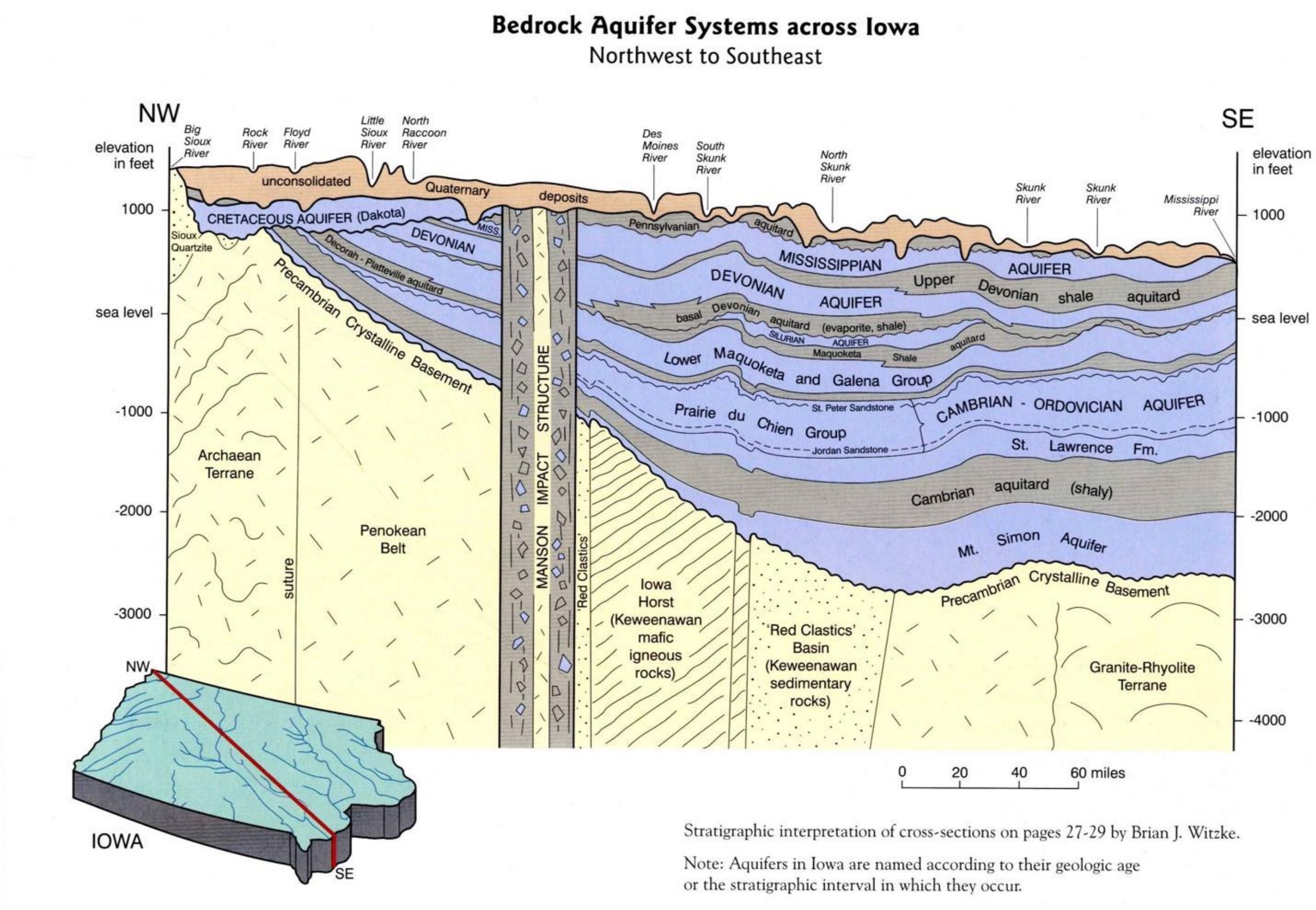
The average amount of the area in Region 5 in various levels of drought or dryness over the period 2000 to 2022 is 37.3% in D0, 20.8% in D1, 9.1% in D2, 1.2% in D3, and 0% in D4. Put another way, on any given week, one might expect about 9% of the region to be in severe drought or worse. D4 drought has never been seen in Region 5 since the USDM's inception in 2000.

C. Location, Probability, and Intensity

No portion of the State of Iowa is immune from drought conditions. Vulnerability to drought is the result of multiple factors. Different communities or sectors draw water from different sources, and each source has different vulnerabilities to shortages based on precipitation, watershed size, infiltration rates, inflow or throughflow (whether riverine or underground flow), and hydrogeological factors like porosity, permeability, etc. Some communities have access to more water sources than others. In Iowa, there is a general geological trend of having access to fewer aquifers in the north and more aquifers in the south. The graphics on the next page illustrate this trend with cross-sections of the aquifers running through Iowa. The difference is especially pronounced in the Northwest to Southeast cross-section. Communities in northwest Iowa may have access to only shallow groundwater, or one or two aquifers, whereas southwest Iowa generally has access to multiple aquifers. These aquifers vary in quality and chemistry, so even communities that can draw from a different aquifer during drought may experience additional costs, health risks, or general unpleasantness from water quality issues.

Bedrock Aquifer Systems across Iowa
Southwest to Northeast





(From: Jean Prior's *Iowa's Groundwater Basics, 2003*)

The most significant impacts associated with drought in Iowa are those related to water-intensive activities such as agriculture, wildfire protection, municipal usage, commerce, tourism, recreation, and wildlife preservation. The following sections explain drought with regard to the major impact sectors of agriculture & irrigation; water supply, energy, & industry; environment & recreation; and public health & safety. This sectoral look includes some discussion on most vulnerable jurisdictions, but sections specifically looking at regional drought vulnerability follow below.

1. *Agriculture and Irrigation Sector*

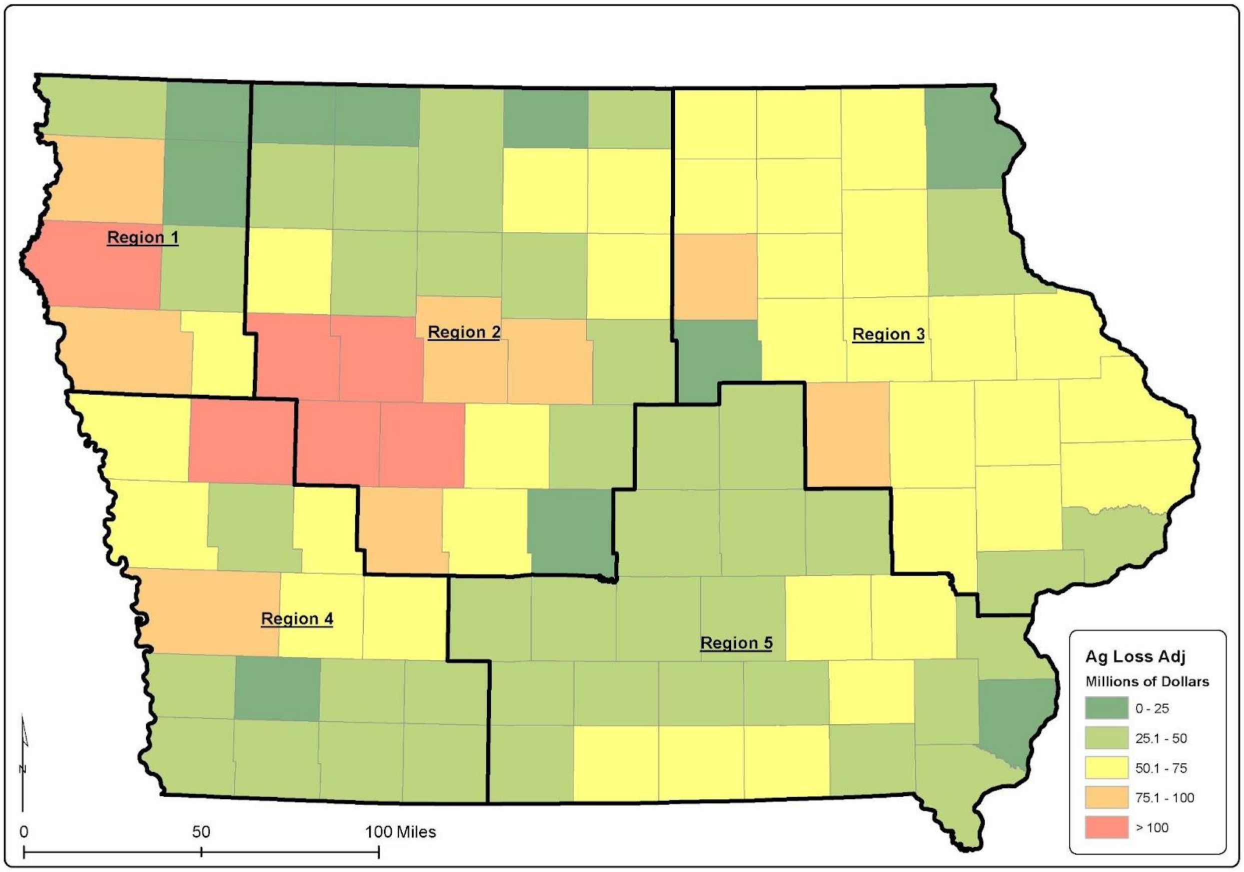
The agriculture and irrigation sector is usually the first sector to be affected by drought conditions. Farmers and ranchers who depend on rainfall for watering crops may be severely affected by even short-term, moderate drought events. In the event of a drought, ranchers lose pasture and forage lands and need to buy expensive supplemental feed. Increased costs often reduce herd sizes, and depleted availability of water for livestock provides additional pressure. Industries that support agriculture are indirectly affected by these stressors. Agriculture and agriculture-related industries accounted for 31% of Iowa's economy in 2017.

Iowa has historically been known for its prime topsoil and its plentiful rainfall and widespread river systems, making it an ideal place for agriculture. Ironically, the plenitude of rain also makes the state vulnerable to drought, since farmers are able to forgo irrigation in most years. Iowa has been said to have a "high risk" rating for drought vulnerability, based on the factors of exposure, sensitivity, and adaptive capacity. Iowa's lack of a comprehensive and ongoing drought plan prior to 2022 has not helped this susceptibility.

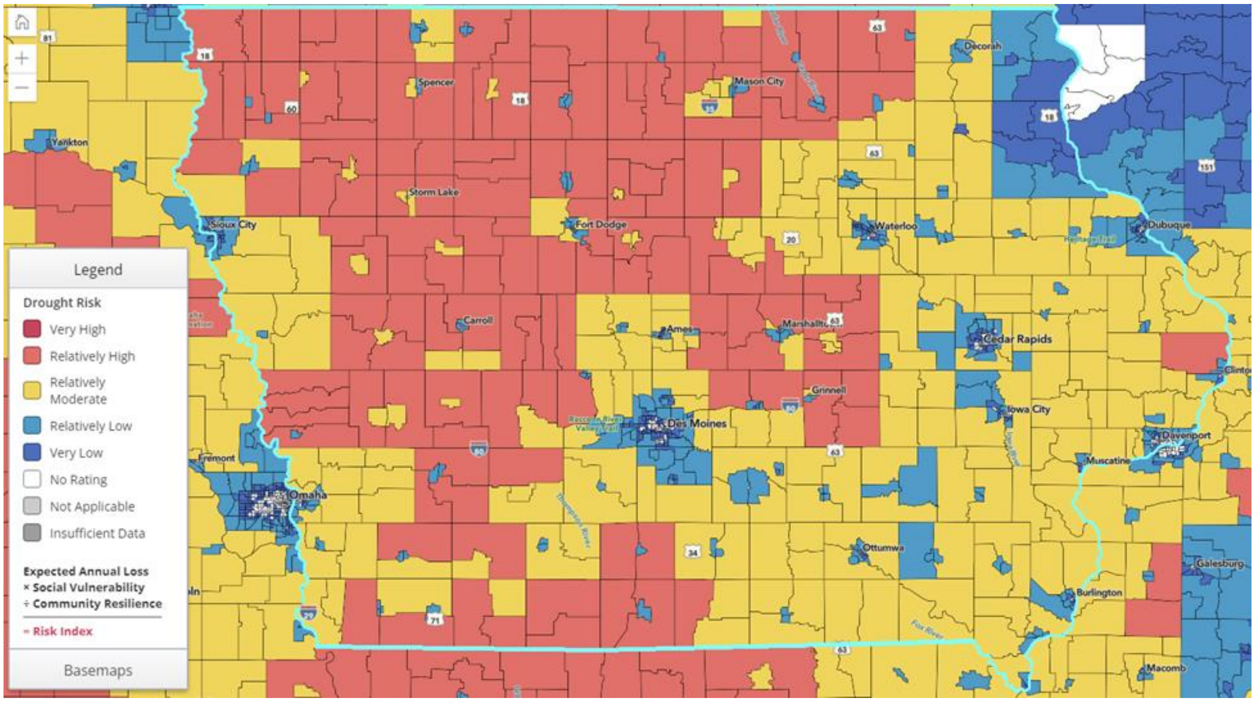
Livestock requires significant amounts of water to stay healthy, especially during extended periods of intense heat. Row crops in most of the state depend on predictable precipitation. In meteorologically drier parts of the state, where irrigation is more common, unfortunately there is the added problem of limited groundwater resources (i.e., they are also geologically drier). Whereas much of Iowa has access to multiple aquifers if one drills deep enough, northwest Iowa is dependent on shallower groundwater resources. If these dry up, the region is doubly vulnerable.

Indicators that can be used to evaluate severity in this sector include reservoir storage levels, surface water and ditch flow levels, soil moisture, observed impacts to crops and livestock, and pasture/ forage conditions. Past drought impact data is available for the agriculture sector from reported losses recorded by the U.S. Department of Agriculture Farm Service Agency and Risk Management Agency (RMA) as part of relief programs. According to the RMA's crop insurance data, the fifteen counties with the greatest losses by dollar value (after adjusting for inflation) in the past 32 years are Carroll, Plymouth, Sac, Crawford, Greene, Calhoun, Pottawattamie, Woodbury, Webster, Guthrie, Hamilton, Butler, Benton, Sioux, and Keokuk.

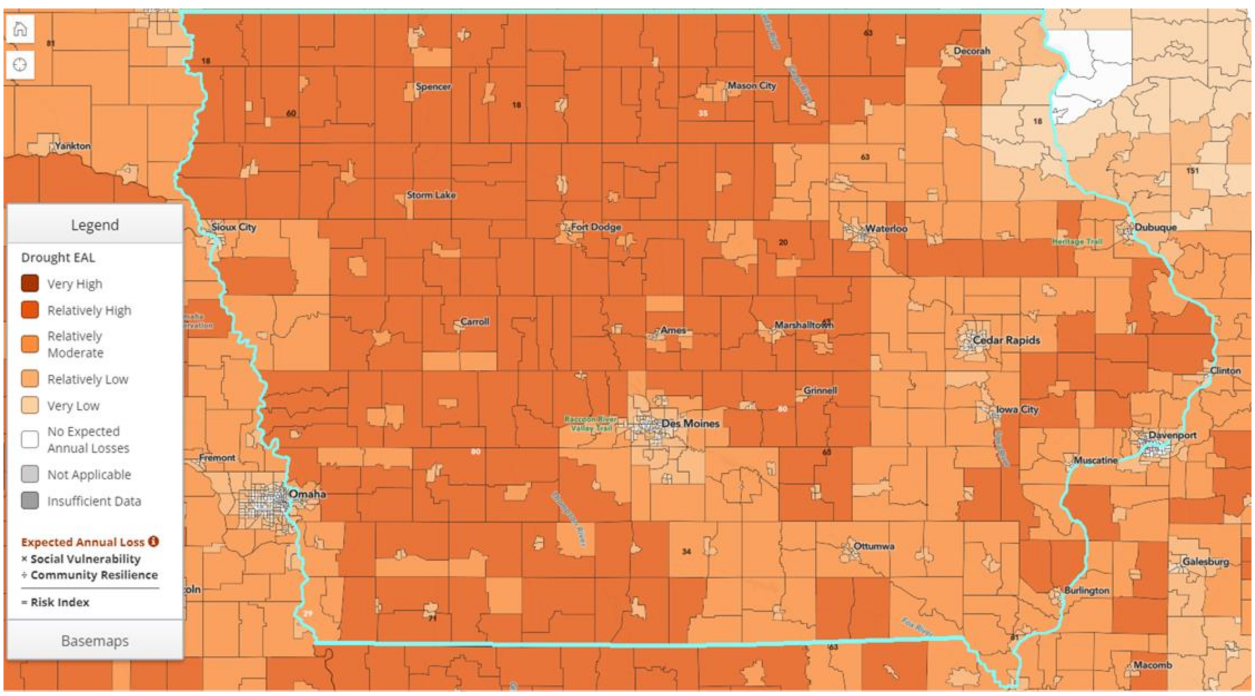
Inflation-Adjusted Crop Insurance Claims (1989-2022)



The following maps summarize an analysis of drought vulnerability from FEMA's National Risk Index (NRI). The analysis considers expected annual loss (EAL), a social vulnerability index (SoVI), and community resilience. The drought risk score for an area is computed by multiplying EAL by the SoVI and dividing by the community resilience rating. These scores are relative to nationwide scores, so Iowa's best or worst ratings may still be worse or better than national averages. The map nonetheless gives an idea of the most vulnerable jurisdictions. EAL is calculated by multiplying exposure by annualized frequency and historic loss ratio. Exposure is the representative value of agriculture potentially exposed to a drought.

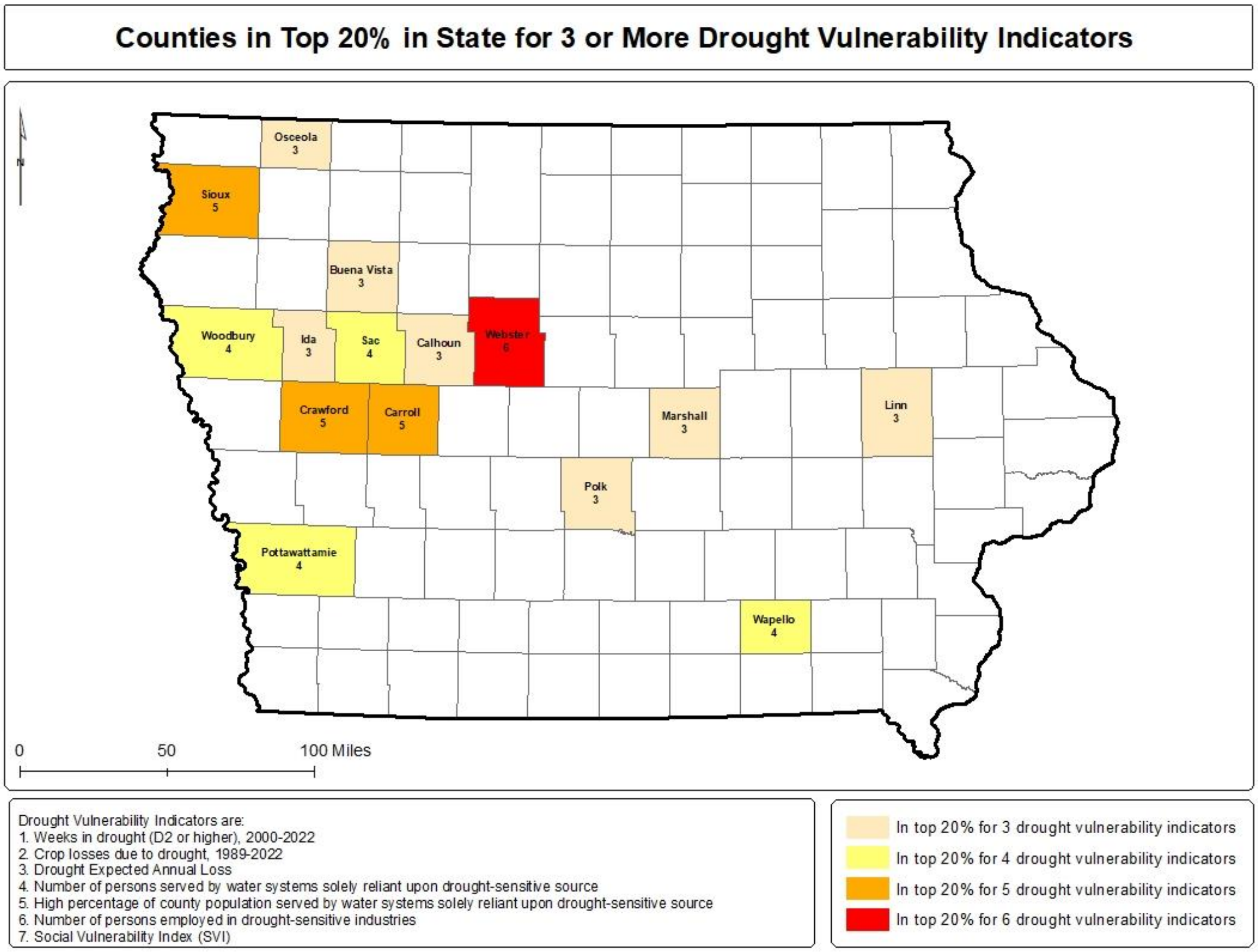


Drought Risk Index by census tract in Iowa, from FEMA NRI



Expected Annual Losses by census tract in Iowa, from FEMA NRI

These maps suggest that most of the jurisdictions more vulnerable to drought are in Drought Zones 1, 2, and 4. According to FEMA's county-based NRI drought risk map, notably at-risk counties include Audubon, Buena Vista, Calhoun, Carroll, Cass, Cerro Gordo, Cherokee, Crawford, Floyd, Franklin, Greene, Hamilton, Hancock, Ida, Kossuth, Marshall, Mitchell, Osceola, O'Brien, Palo Alto, Pocahontas, Poweshiek, Ringgold, Sac, Tama, Webster, Winnebago, and Wright. No census tract in Iowa falls under the "Very High" levels of EAL indicated in the map legend. Most are either relatively high or relatively moderate on the nationwide scale. The counties with the highest Expected Annual Losses (EALs) are Buena Vista, Sioux and Kossuth; the EAL for these counties



is over $4 million each. The drought EAL for the entire state, inclusive of all counties, is over $163 million (based on the FEMA NRI[40] as of December 2022).

Unfortunately, the data in the NRI drought risk index are based on agricultural loss data alone, so effects on urbanized areas are generally ignored in these maps. However, this focus is not entirely inaccurate, since agriculture in Iowa is often the first sector to be affected, leaving rural agricultural areas generally more vulnerable to drought.

Unlike many other industries in Iowa, agriculture is one that is often insured against drought. The damages sustained thus might not register as a declared disaster under FEMA disaster relief programs or even USDA disaster relief programs. The economic impact to the agricultural sector as a whole, then, is absorbed to an extent by insurance. This is not a long-term solution to potential crop shortages that may

[40] https://hazards.fema.gov/nri/map

result from a dependence on crop insurance as a drought mitigation measure. Additionally, many other industries in Iowa are dependent on productive cropland (e.g. ethanol, livestock, food processing, chemical processing, etc.), as discussed below.

2. *Water Supply, Industry, & Energy*

Water supply is at the root of drought resilience for many sectors addressed in this plan, but this sector can itself be vulnerable to drought. Precipitation, streams, rivers, lakes, reservoirs and groundwater are used to meet a diverse set of water resource needs within the State. Each of these water sources can be impacted during drought periods, resulting in a complex interlinked array of environmental, economic and societal impacts. The following points summarize drought impacts related specifically to the State's water resources.

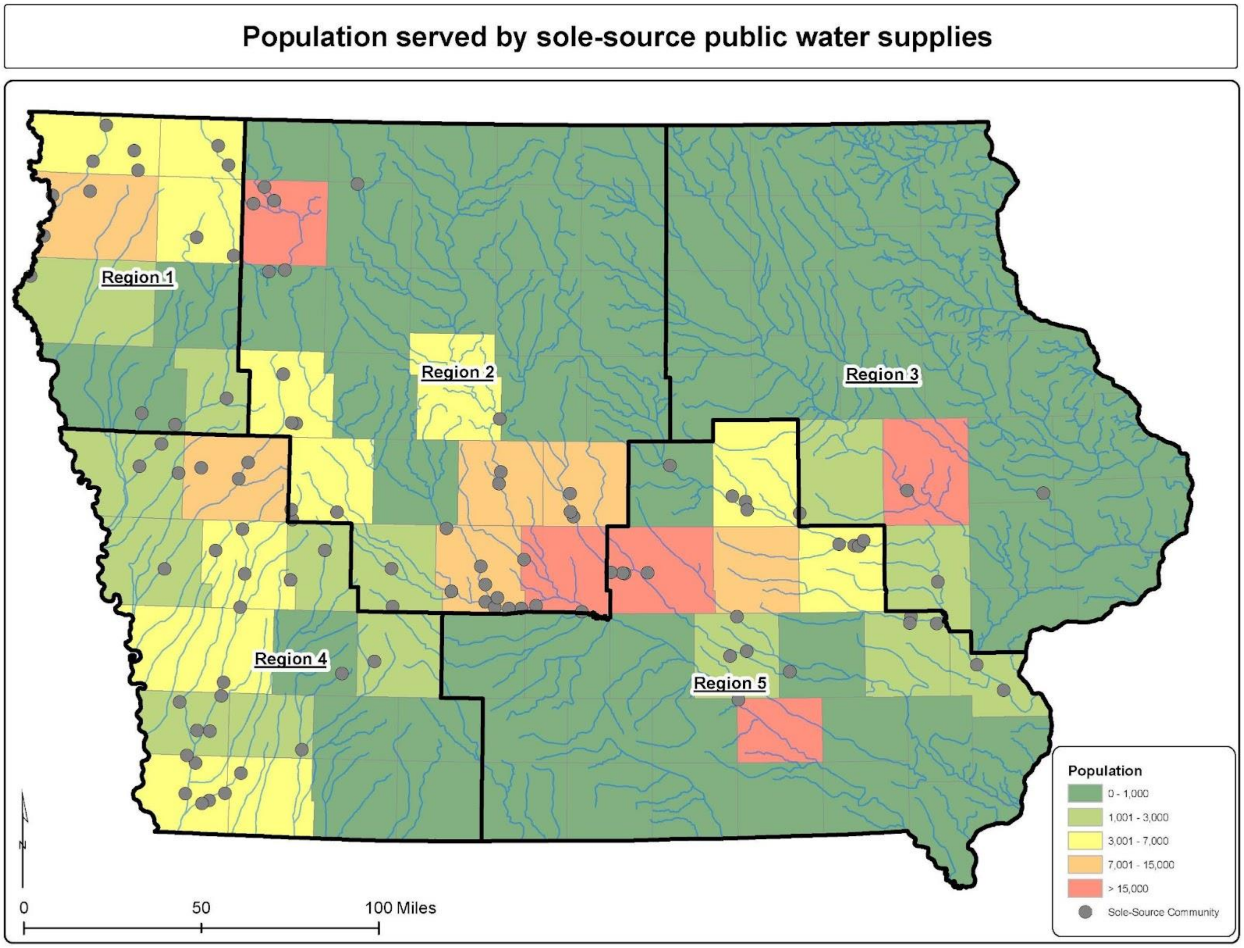
Lower precipitation – During dry periods, precipitation in the form of both rain and snow is below normal, resulting in less moisture in the soil, less runoff into the streams and less recharge to the underlying aquifers.

Lower streamflows – Reduced runoff results in lower stream flows which can reduce water availability to water users that divert directly from the stream. Reduced streamflow can also bring water levels below diversion intake elevations and result in a variety of adverse impacts to river navigation, hydroelectric power production, water quality, and aquatic habitat.

Lower lake and reservoir levels – Less runoff can result in lower lake and reservoir levels causing a variety of recreational and environmental impacts. Water supply availability can also be stressed in regions where water users rely on reservoir storage to meet their needs.

Decline in groundwater levels – Groundwater levels can decline, increasing well pumping costs and causing shallow wells to dry up. Natural systems such as wetlands that depend on shallow groundwater can also be adversely impacted.

Various water supply systems in Iowa may depend on streamflow, aquifer levels, shallow groundwater, and lake & reservoir levels - some depend on more than one. A public water supply system might be considered most vulnerable if it relies solely on groundwater found in alluvial sand and gravel from an interior body of water, or if the loss of wells pulling from these sources could not be compensated by other wells in the system accessing other source waters. Such vulnerable systems, shown in the map below, are more sensitive to a loss of streamflow, which is affected by precipitation. A drought may be especially challenging for these systems. Certain counties have significant populations served by these systems, clustered primarily on the western edge of the state and in a belt across the center of the state. Clay, Jasper, Linn, Polk, and Wapello counties have more than 15,000 people on sole-source water supply systems; while Boone, Crawford, Dallas, Poweshiek, Sioux, and Story counties have between 7,000 and 15,000 people on these systems.



Community Water Supplies dependent on alluvial sand and gravel groundwater, Iowa DNR

Shortages in available water can lead to increased operating costs and/or difficulty meeting regulations for both water supply and water treatment systems. In dry times, water suppliers may find that pollutants in their water sources are more concentrated (less water to dilute pollutants). This means even what water still exists in the supply might near or exceed allowable limits on pollutants in a public water supply. Similarly, water treatment plants are typically restricted in how concentrated their effluent can be compared to the stream as a whole. At low streamflows, these limits will be lower and thus harder to avoid exceeding.

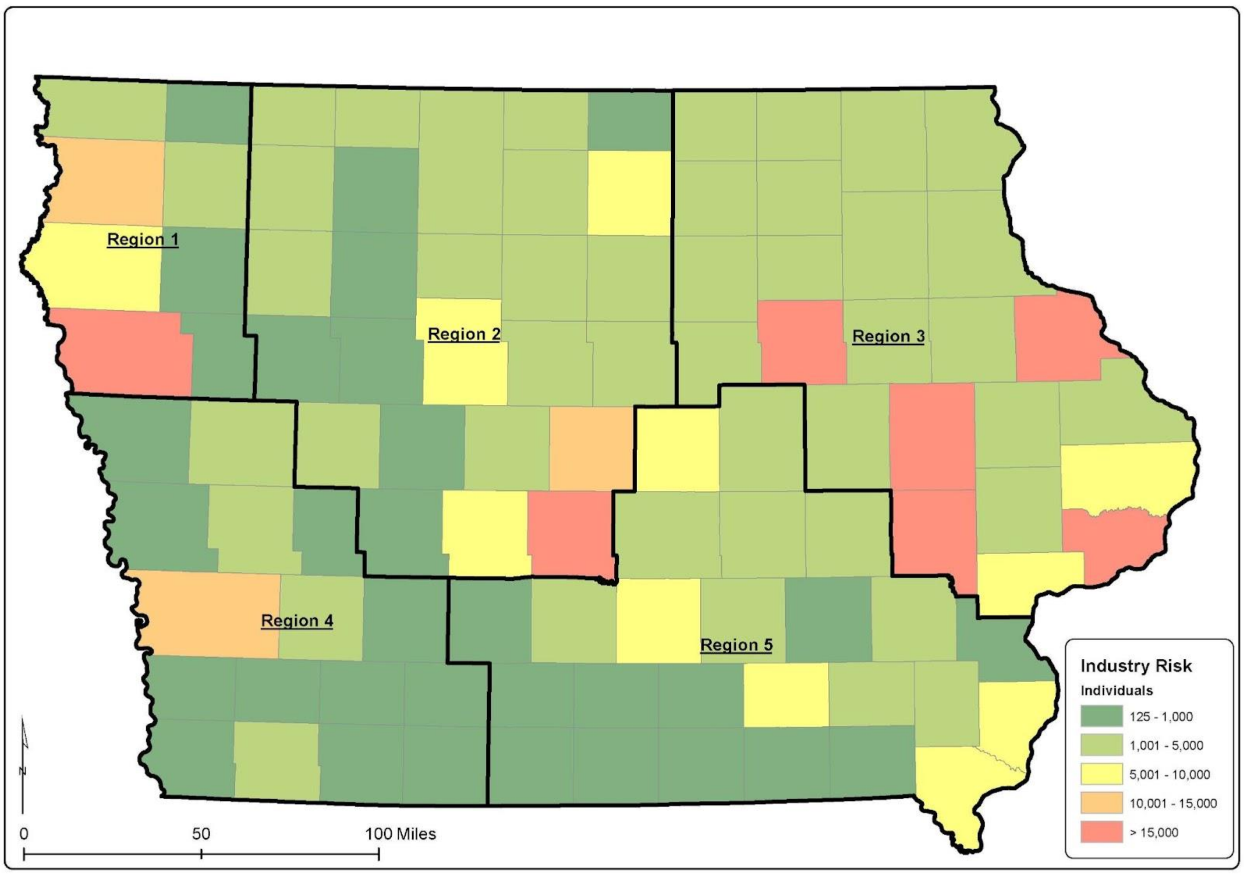
To avoid such difficulties, most water supply, distribution, and treatment systems will prepare reserve supply capacity and/or limit demand (either by not building out beyond what the system can handle at its peak, or by requesting users to restrict usage). Some systems in small towns, however, may not be able to afford the excess capacity or were built when demand better matched supply and economic capacity.

Major industries in Iowa include manufacturing (including chemical, machine/vehicle, & light manufacturing), renewable fuel and energy, insurance & banking, health and social services, food processing, warehousing & distribution, and IT & data centers.

Of these, certain industries are major water users. For instance, Iowa's industrial water users with annual usages over 500 million gallons per year (mgy) are from the following industries, from highest to lowest use: manufacturing, food processing, chemical processing, and ethanol. These industries are highly dependent on the availability of water. Loss of access to a usable water supply can lead to constraints on production. Fortunately, most of these highest water users in the state (i.e. over 500 mgy) are clustered around rivers and/or in counties on the eastern half of the state with less drought vulnerability (from highest to lowest use, by county: Muscatine, Wapello, Clinton, Black Hawk, Linn, Lee, Woodbury, Webster, Cherokee, Dubuque, Chickasaw), i.e. mostly Drought Regions 3 and 5.

Data from the U.S. Census Bureau show a similar pattern: over a third of vulnerable non-agricultural industries operating in Drought Region 3 (about 212,000 employees; compared to about 160,000 in Region 2; 62,000 in Region 5; 40,000 in Region 1; and 27,000 in Region 4).

Employees in industries at risk of drought



Despite the concentration of the highest water-using facilities in these relatively drought-safe places, there is still a secondary risk from drought in the form of decreased raw materials when agriculture is affected. Ethanol production depends on growing more corn than what is produced for food. Food processing and chemical manufacturing depend on crops and livestock and their byproducts. Farm equipment manufacturing, a significant part of Iowa's manufacturing sector, is dependent on farmers and ranchers having sufficient income or credit to purchase new equipment. Finally, reduced production of food (especially if it occurs in other regions as well) can lead to higher food prices economy-wide, which restricts expendable income and hampers economic vitality.

Additional risk to industry in Iowa comes from low river levels where barges carry products along the Mississippi and Missouri rivers. The droughts from 2020 to 2022 have led to levels so low on the Mississippi that barges have been under-laden to ensure they can float on the shallow river. This makes transportation of products, notably agricultural products, more difficult and costly.

For over a decade, Iowa has been a net producer of electricity, creating more than it uses. Iowa itself may not feel the effects of drought on electricity supply, but in an interstate market, the state may still see prices change if drought causes power shortages elsewhere. A reduction of electric power generation and water quality deterioration are potential effects of drought. Hydroelectric power accounts for only 1.3% of the state's electric generation, but large amounts of water are also used in cooling generators in coal and nuclear plants. Consequently, the water that flows out after cooling may be too warm to safely put into a river or stream with low flow (the higher concentration of warm or hot liquid could be detrimental to the stream's health). The energy industry's vulnerability to drought does not come necessarily from a lack of water for cooling, but difficulty in disposing of that water safely and legally.

3. Environment and Recreation Sector

Along with regular precipitation, wetlands and other surface waters are vital to the survival of wildlife, including plants and animals. An ongoing drought which severely inhibits natural plant growth cycles may impact critical wildlife habitats. Drought impacts increase with the length of a drought, as carry-over supplies in reservoirs are depleted and water levels in groundwater basins decline.

Fish populations can be affected directly by water shortages or indirectly by water quality problems caused by drought. Higher nutrient concentrations due to drought (especially following precipitation that washes built-up nutrients after a dry period) can lead to bacterial or algal blooms, decreasing the oxygen available to fish. This exacerbates the already decreased amount of dissolved oxygen available to each fish when the volume of water decreases. Hunters may also have trouble finding animals when watering holes dry up.

Migratory animals are especially dependent on water being available when they pass through, but water shortages can be difficult for any plants or animals. Much of the outdoor recreation in Iowa is also tied to the presence of water, whether hunting, fishing, boating, or camping. Even non-water-adjacent recreation can become less desirable when plant and animal life is negatively affected by drought. The US Department of Commerce's Bureau of Economic Analysis places the contribution of the outdoor recreation industry at about 1.8% of Iowa's GDP ($3.6 billion) in 2020.

Drought conditions increase the risk of wildfires, which can mean prohibitions on camping fires. During drought, public recreation areas may be closed to prevent human-caused wildfire due to desiccated hunting areas or hiking trails – the number of these closures can be used as an indication of the severity of drought affecting the environment as well as public safety.

Other indicators of drought are increased tree mortality due to lack of precipitation and increased vulnerability to disease due to plant water stress. Related to this is a decrease in hunting game population due to lack of forage and water. Some of these indicators are simple to record and quantify, e.g., the number of days a hunting area is closed; while others are more difficult to ascertain, e.g., tree mortality or reduction in game population in areas difficult to access.

4. *Public Health and Safety Sector*

Drought can have a number of effects on the public health and safety sector. The most obvious problem is a lack of access to water for human consumption and sanitation. These, however, are the best-protected uses of water in Iowa's water prioritization scheme. Other sectors (e.g. irrigation or industry) will typically be restricted first. That said, when drought is severe enough to seriously affect an urban population's water supply, the consequences on human health and wellbeing are potentially significant. Furthermore, the impacts of drought on public health and safety can be seen before the state sees any actual restrictions on domestic supply.

As mentioned above, the agricultural sector is usually the first affected by drought. This cascades to the public health sector due to the potentially devastating mental health toll that crop and livestock losses can take on farmers, ranchers, and rural communities, especially those lacking insurance.

Drought can concentrate pollutants in effluent from industry and water treatment plants, further reducing clean, usable water even where it is available. Switching to alternative water sources may mean dealing with water quality issues not normally an issue for a community. One stakeholder noted that their community's backup water supply is polluted with PFAS (per- and polyfluoroalkyl substances), leading to questions of allowable PFAS limits when water supply is short.

Prolonged periods of drought can create dry landscapes that are vulnerable to wildfire hazard, but short drought periods also have the ability to increase the risk of wildfire hazards. Furthermore, depending on a community's water supply source, its ability to fight fires that do break out may be diminished by low water supply.

Drought conditions can also cause soil to compact, decreasing its ability to absorb water, making an area more susceptible to flash flooding and erosion. Consequently, the state may simultaneously see the disastrous effects of excess water at the same time as the effects of insufficient water. A drought may also increase the speed at which dead and fallen trees dry out and become more potent fuel sources for wildfires. Drought can make trees more susceptible to insect infestations, causing more extensive damage to trees and increasing wildfire risk, at least temporarily. Trees in urban forests can also become susceptible to insects and mortality due to lack of water.

Drought has been linked to the spread of diseases, notably West Nile Virus, flavivirus, and St. Louis encephalitis. This is due to the increased ability of mosquito populations to increase in urban drainage systems during times of decreased rainfall. Because once-flowing water may pool in dry conditions, there is more standing water for mosquitoes to use, located in places not normally a concern. At the same time, places where there may normally be standing water could be dry during a drought, giving mosquitoes less opportunity to reproduce. The net effect of any given drought on mosquito populations in any given area is uncertain, but has potential for benefit or harm.

Valley Fever (coccidiomycosis) can also be expected to spread to new areas, as the fungal spores that cause the disease are "increasingly aerosolized by drought conditions, making them easier to inhale." Long drought periods followed by intense rain are also positively associated with increases in disease outbreaks due to increased rodent populations, notably the 1993 outbreak of Hantavirus in the southwestern U.S.

Drought contributes to harmful algal blooms, endangering human health both via drinking water and recreational activities. This has become a common hazard in Iowa, whose waters also suffer from nitrogen pollution due to runoff from livestock facilities, fertilized croplands, and lawns, which exacerbates cyanobacteria growth. Water-borne diseases such as Escherichia (E). coli, Cryptosporidium, and Giardia can also become concentrated in groundwater sources during drought, which after rainfall can contaminate water sources, especially around livestock and places where livestock manure is applied or allowed to leach into water sources. Heavy rainfall during or after an extended drought can also lead to outbreaks of Campylobacteriosis and other diseases.

Despite being located at the confluence of two rivers, the water supplier for the state's largest metropolitan area (Des Moines Water Works) has been working to employ multiple water sources and supply strategies (e.g., backup wells, flash boards, aquifer storage and recovery) due to issues with surface water quality and quantity. This insulates the Des Moines metropolitan area from some of the exacerbated water quality issues from drought, but smaller communities with less adaptive capacity have to deal with the same deteriorated water quality and quantity. Thus even in the public health sector, larger urbanized areas that have prepared for water quality issues may be less severely impacted by drought. As regards public health and safety, the most at-risk populations will be located in rural and urban areas with less adaptive capacity.

5. *Regional Risk*

As discussed above, the general trend of regional vulnerability is a spectrum (from most vulnerable to least) going northwest to southeast, rural to urban, and shallow/surface water to deeper groundwater. The state's drought plan establishes five drought regions: northwest, central, northeast, southwest, and southeast. Within each of these regions, different jurisdictions are more vulnerable than others due to their type of water supply, their access to multiple types of water supply, their dependence on agriculture or other industries vulnerable to drought, etc. Below, the vulnerability of each Drought Region is discussed as it relates to crop insurance claims, employees in drought-vulnerable industries, state parks (as a proxy for environment and recreation), climate, and populations served by vulnerable water supply systems.

While not specific to single regions, precipitation outside of the state of Iowa will also affect Iowa's water supplies. The entirety of Iowa's eastern and western borders are major rivers. Snowmelt and precipitation principally from Minnesota, Wisconsin, Colorado, Nebraska, North and South Dakota, Wyoming, and Montana feed the Mississippi and Missouri Rivers in Iowa. Many of these states are or could be experiencing their own droughts, meaning not only less water flowing downriver, but increased demand in those states, decreasing the flow to Iowa. With the warmer average winter temperatures anticipated, mountain snowpack may decrease, and spring snowmelt in the Rocky Mountains may come earlier in the year. With over 30% of the Missouri River's annual flow coming from the mountains, it is especially prone to decreased flow, relative to Iowa's other rivers. Regions 1 and 4 would feel this effect more than others.

Region 1: Northwest

Region 1 is not only meteorologically drier than other regions, but it also relies heavily on groundwater from shallow alluvial aquifers or deeper bedrock aquifers, making it more vulnerable to water supply shortages during drought. The area is largely agricultural, but more than most regions, it is also served by farm irrigation, primarily near the Missouri River. Water supply stakeholders expressed a concern with water demand from livestock in this region. Especially on hot days, livestock can require significant amounts of water not only for consumption, but for cooling. In Region 1, there are about 28,000 people served by water supply systems dependent on alluvial sand and gravel groundwater.

Notable at-risk non-agricultural industries in Region 1 include healthcare and social assistance, chemical manufacturing (including ethanol), food manufacturing, metal and machinery manufacturing, transportation, and construction. Region 1 has a higher concentration of ethanol production plants than most regions, especially relative to population. Advances in technology since the turn of the century have led to a much lower water-to-ethanol ratio in the production process, so water availability, while still a concern during drought, will have less impact than it would have in decades past. However, the availability of corn, which is largely dependent on precipitation in Iowa, can still be impacted by drought. Plymouth, Woodbury, and Sioux counties were in the top 15 Iowa counties for agricultural losses due to drought claimed from 1989 to 2022. Non-agricultural industry risk in Region 1 is concentrated in Woodbury, Sioux, and Plymouth counties. There is one state park in Region 1, in Woodbury county. This is the lowest ratio of parks per county in a drought region.

Region 2: Central

Region 2 has some of the most productive soils in the world, but the row crop agriculture that dominates the landscape is vulnerable to precipitation deficits, as relatively little of it is irrigated. Still, the region has access to both bedrock aquifers and groundwater from alluvial sand and gravel aquifers. In Region 2, there are about 95,000 people served by water supply systems dependent on alluvial sand and gravel groundwater.

Notable at-risk non-agricultural industries in Region 2 include healthcare and social assistance, chemical manufacturing (including ethanol), data processing and hosting (which often need water for cooling), printing and publishing, plastics and rubber manufacturing, food manufacturing, metal and machinery manufacturing, transportation, construction, utilities, waste management, and wood product manufacturing. There is a notable concentration of commercial feedlots along the I-35 corridor in Wright, Hamilton, and Hardin counties.

Carroll, Green, Calhoun, Webster, Guthrie, and Hamilton counties were in the top 15 Iowa counties for agricultural losses due to drought claimed from 1989 to 2022. Non-agricultural industry risk in Region 2 is highest in Polk, Story, Cerro Gordo, Webster, Dallas, Buena Vista, Carroll, and Boone counties. There are 27 state parks in Region 2, with 10 in Dickinson county, two each in Cerro Gordo, Emmet, Polk, and Webster counties, and one each in Boone, Calhoun, Franklin, Guthrie, Hancock, Hardin, Kossuth, Sac, and Winnebago. This region has the highest ratio of state parks to counties. The high number of parks in Dickinson County is related to the presence of Iowa's "Great Lakes" region, a regional hub for water-based recreation and tourism. Saylorville Lake, a large reservoir just north of Des Moines, is also in Region 2. An exceptional drought could pose a threat to these lakes and the ecosystems and industries that depend on them.

Region 3: Northeast

Plentiful water resources lead to Region 3 being perhaps the least drought-vulnerable region, at least on the supply side. However, the availability of water beneath the surface does not imply its accessibility. Furthermore, with most farmland in this region not being irrigated, crops are still vulnerable when drought comes. In Region 3, there are about 145,500 people served by water supply systems dependent on alluvial sand and gravel groundwater. Most of them (about 141,000) are on the Cedar Rapids municipal system.

Benton and Butler counties were in the top 15 Iowa counties for agricultural losses due to drought claimed from 1989 to 2022. Non-agricultural industry risk in Region 3 is highest in Linn, Scott, Johnson, Black Hawk, Dubuque, Muscatine, Clinton, Bremer, and Winneshiek counties. There are 16 state parks in Region 3, with two each in Linn and Muscatine counties, and one each in Allamakee, Black Hawk, Buchanan, Clayton, Delaware, Dubuque, Fayette, Johnson, Jones, and Winneshiek.

Region 4: Southwest

Groundwater resources in Region 4 are generally limited to shallower wells, as deeper aquifers have poor water quality. Surface water rounds out the water supply, and many water users are connected to rural water systems. In Region 4, there are about 38,500 people served by water supply systems dependent on alluvial sand and gravel groundwater.

Crawford and Pottawattamie counties were in the top 15 Iowa counties for agricultural losses due to drought claimed from 1989 to 2022. Non-agricultural industry risk in Region 4 is highest in Pottawattamie, Crawford, and Page counties. There are 12 state parks in Region 4, with two each in Fremont, Monona, and Pottawattamie counties, and one each in Cass, Harrison, Montgomery, Shelby, Taylor, and Union counties.

Region 5: Southeast

Drought region 5 is similar to region 4 in that water users generally depend on shallow groundwater. However, the eastern part of the region has access to deeper water sources and the southwestern part of the region is home to the Rathbun Rural Water System, which draws water from a large reservoir (Rathbun Lake) and serves about six and a half of the 25 counties in Region 5. In Region 5, there are about 67,000 people served by water supply systems dependent on alluvial sand and gravel groundwater.

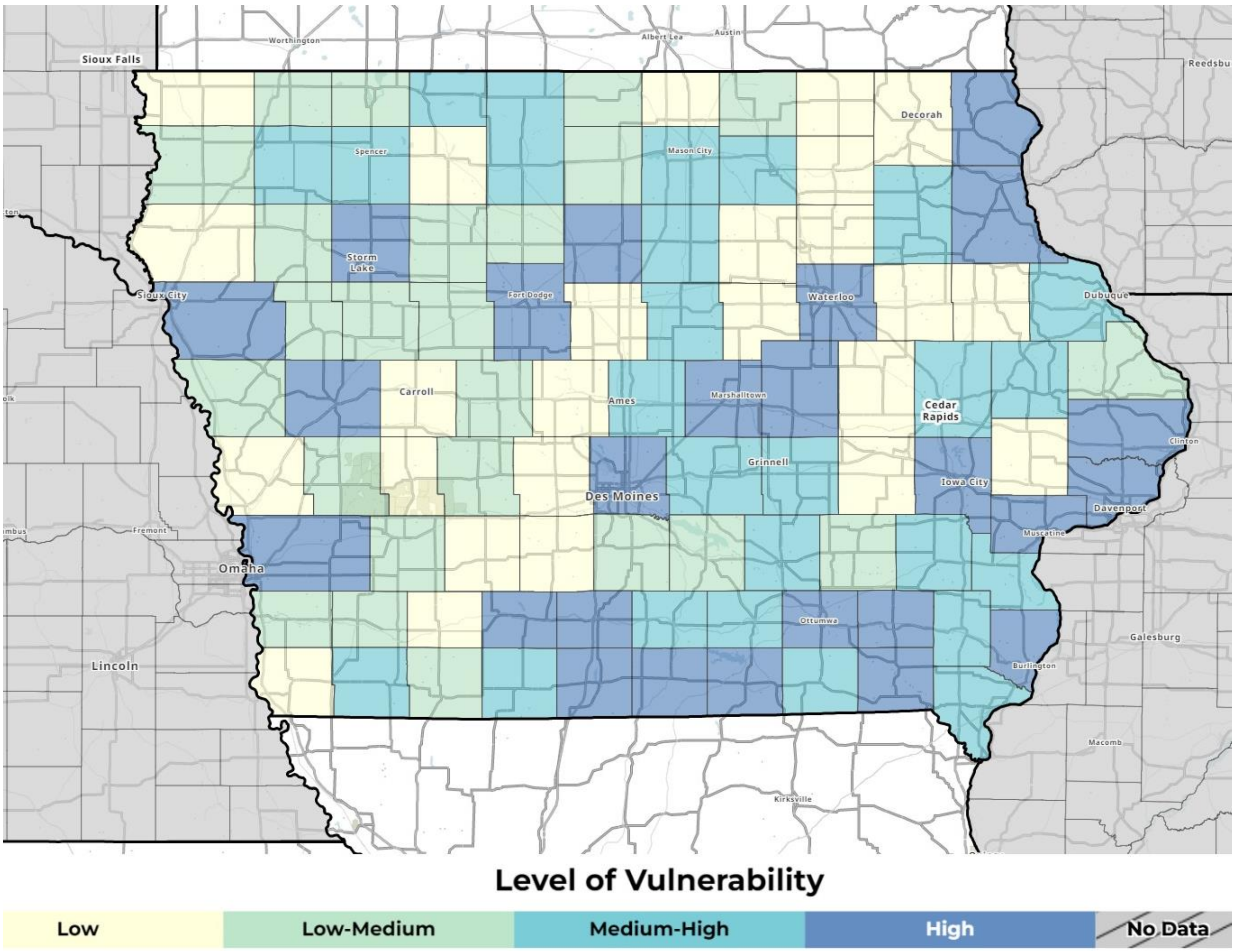
Keokuk was the only county from Region 5 in the top 15 Iowa counties for agricultural losses due to drought claimed from 1989 to 2022. Non-agricultural industry risk in Region 5 is highest in Marion, Des Moines, Marshall, Lee, Wapello, Jasper, Henry, Poweshiek, Washington, and Warren counties. There are 17 state parks in Region 5, with two each in Appanoose, Lucas, Van Buren, and Warren counties, and one each in Davis, Decatur, Henry, Jasper, Madison, Mahaska, Marion, Tama, and Washington counties.

D. Summary of Vulnerability: Most Vulnerable Areas

The analyses provided in the section above identified different areas in the state most vulnerable to several different impacts of drought. Carroll, Plymouth, Sac and Crawford counties have experienced the most agricultural loss (based on crop insurance claims). According to FEMA's NRI methodology, the counties that have the highest expected annual losses due to drought are Buena Vista, Sioux, Kossuth, and Sac (each one having an EAL over $4 million). Clay, Jasper, Linn, Polk, and Wapello counties have more than 15,000 people each on sole-source water supply systems that are at more risk to drought than other water supply systems. Counties with the most employees in industries that are at risk to drought are: Polk, Linn, Scott, Johnson and Black Hawk. The counties that have spent the most weeks under drought conditions (D2 or higher on the USDM) are Sac, Calhoun, Carroll, Plymouth and Buena Vista.

Besides all these factors, another factor to consider when evaluating the vulnerability of jurisdictions to drought is social vulnerability.

The US Centers for Disease Control (CDC) has developed a Social Vulnerability Index (SVI) that uses 16 US Census variables to measure and identify communities that may need support before, during or after disasters[41]. The map below shows how counties in Iowa rank, relative to one another, on the SVI measure. The counties shown as "High" level of vulnerability rank in the top quartile of Iowa's counties for social vulnerability (according the SVI). The SVI is just one more important factor to consider when determining how vulnerable jurisdictions are to drought.



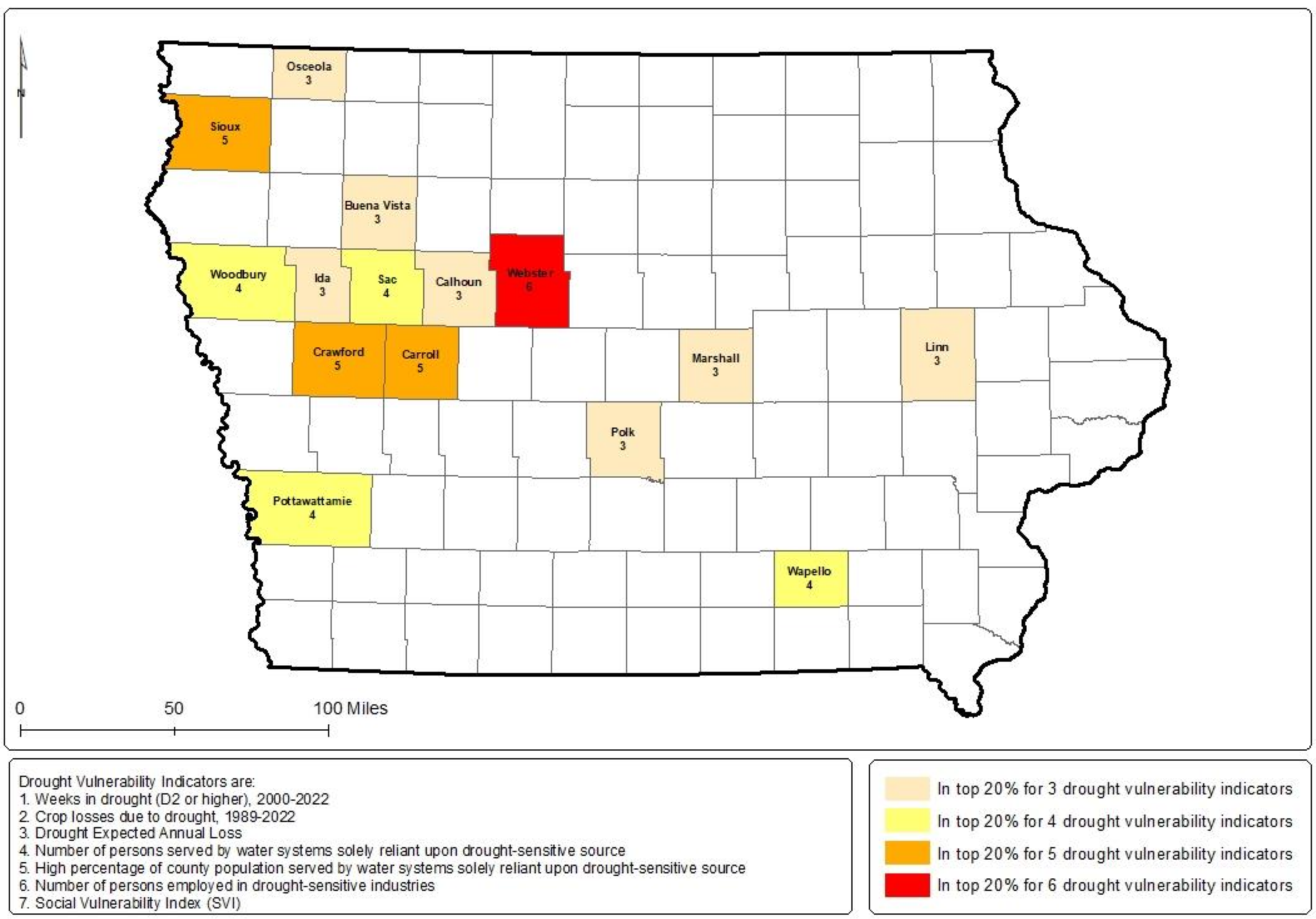
Many factors to consider for drought vulnerability have been presented. Any county that finds itself vulnerable under multiple factors would be especially vulnerable to drought. The map below shows the counties that are "most vulnerable" for 3 or more factors. The factors presented, and discussed in more detail above, are:

[41] See CDC Social Vulnerability website at https://www.atsdr.cdc.gov/placeandhealth/svi/index.html

1. Weeks in drought (D2 or higher), 2000-2022
2. Crop losses due to drought, 1989-2022 (from RMA crop insurance claims)
3. Drought Expected Annual Loss (per FEMA NRI)
4. Number of persons served by water systems solely reliant upon drought-sensitive source (alluvial sand and gravel groundwater)
5. High percentage of county population served by water systems solely reliant upon drought-sensitive source (alluvial sand and gravel groundwater)
6. Number of persons employed in drought-sensitive industries
7. Rank, among Iowa counties, on CDC's Social Vulnerability Index (SVI)

To be considered "most vulnerable" in regards to any particular factor, the county must be in the top 20% of counties for that particular factor. Webster County was in the top 20% for six different factors. Counties in the top 20% for five factors were: Carroll, Crawford, and Sioux. Counties in the top 20% for four factors were Sac, Wapello, Woodbury, and Pottawattamie. Counties in the top 20% for three factors were Calhoun, Buena Vista, Ida, Polk, Osceola, Marshall, and Linn.

Counties in Top 20% in State for 3 or More Drought Vulnerability Indicators



E. Summary of Problem and Identification of Possible Actions to Mitigate Problem

Drought ultimately arises from a lack of precipitation, which is generally outside our control. Supply can still be supplemented by maintaining reserve capacity and encouraging conservation of water resources when they become scarce. Much (but not all) of the work of drought mitigation is local, whether done by households, industries, governments, or otherwise. Having information as early as possible as to when an area may be entering drought and how people can or should start preparing reserves or reducing use will help communities respond appropriately. Consequently, the state's responsibilities lie primarily in preparing local communities for drought. To that end, the following mitigation goals are proposed:

1. Improve public understanding of drought and water supply; create a culture of conservation
2. Improve data collection and analysis capabilities
3. Coordinate information and messaging from state agencies to improve public response
4. Improve infrastructure resilience against drought
5. Improve resilience and responsiveness of agriculture, industry, and natural resources
6. Build on local capacity in preparing for and responding to drought

Possible measures for meeting the above goals and mitigating drought impacts in Iowa are:

1.1	Develop coordinated, prompt, reliable, and accessible information for the whole community, actionable at every level of organization (i.e. state agencies, local government, industries, NGOs, individuals), concerning current and likely drought and water supply status.
1.2	Encourage and support public education on drought vulnerability, drought-time response actions, and continuous conservation measures prior to the occurrence of drought. Work with Iowa Department of Education to promote awareness among students
1.3	Promote a culture of conservation through public messaging and discussion with water suppliers. Conservation education or outcomes could be tied to the receipt of funds for infrastructure
2.1	Characterize Iowa's surface and groundwater resource availability, quality, use, and sustainability, and share the information via a web-based data system. Establish an "Iowa Drought Information System", similar to the existing Iowa Flood Information System.
2.2	Expand current network of stream gauges to improve monitoring. Focus expansion on watersheds with insufficient or non-ideal placement of gauges
2.3	Expand current network of rain gauges to improve rainfall monitoring.
2.4	Expand current soil moisture monitoring network.
2.5	Continue to improve groundwater level monitoring (i.e. install more monitoring wells)
2.6	Encourage public use of CMOR.
2.7	Incentivize or require water suppliers to confidentially share supply and demand forecasts with the Drought Coordinating Team
2.8	Improve mapping of private water supply and private wastewater systems; ensuring they can be assessed during extreme weather emergencies. In Iowa, the Groundwater Hazard Statement is required for all property transfers involving private water/wastewater systems. Capturing the data in GIS may improve risk assessment during drought.

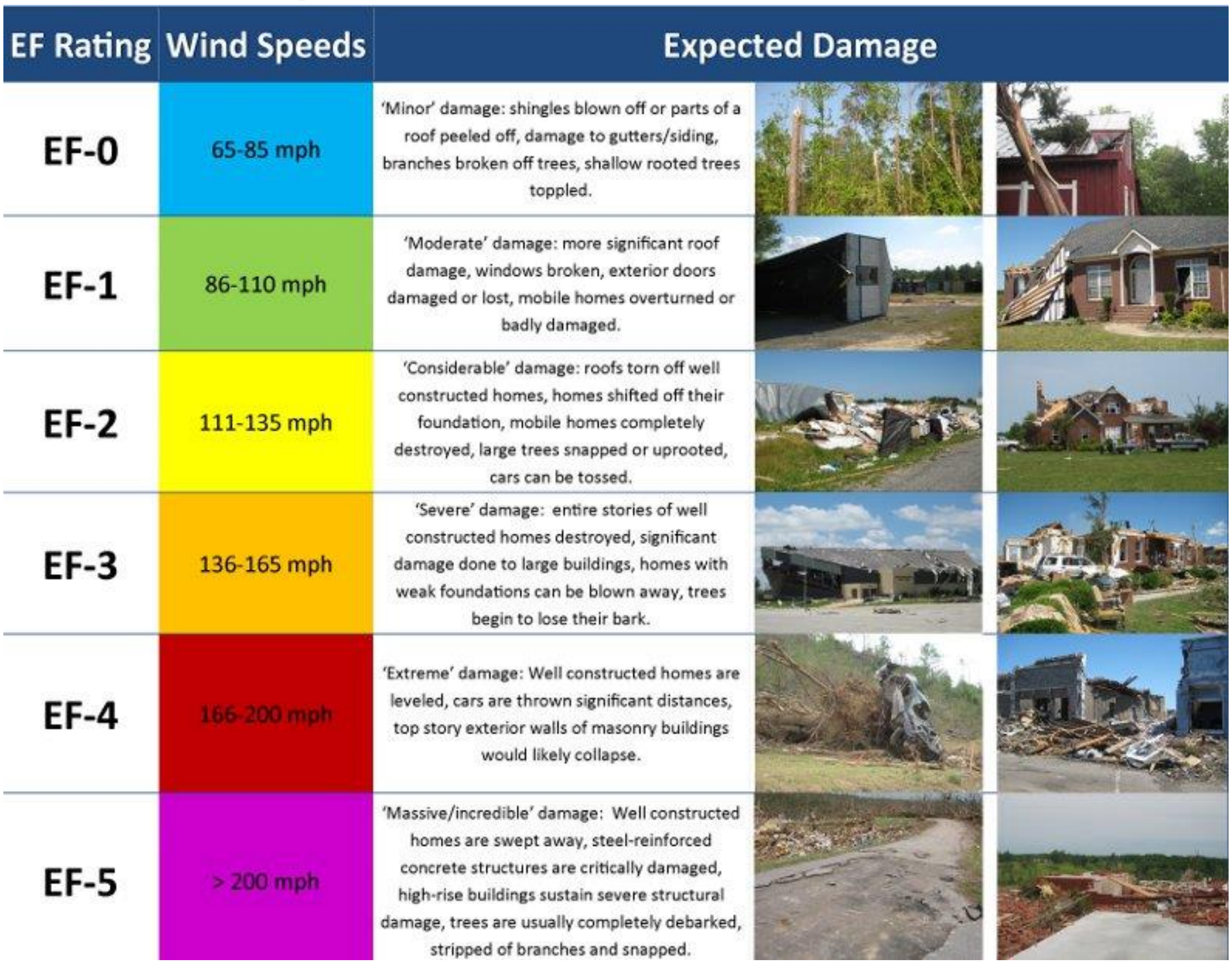
3.1	Implement the Iowa Drought Plan communication plan.
3.2	Develop a framework to coordinate interagency drought-related efforts and communication.
3.3	Provide water suppliers with prepared materials for distribution to water users, appropriate to the drought level and region.
4.1	Encourage and implement green infrastructure practices to create healthier urban environments and manage stormwater in cities. Practices include mechanisms that prevent soil erosion or provide improved infiltration & groundwater recharge, flood protection, habitat, and cleaner air & water.
4.2	Encourage local ordinances to exempt drought-resistant native plantings from vegetation height restrictions.
4.3	Expand drought-resistant native plantings along highways and local roads.
4.4	Foster riparian buffers on private lands.
4.5	Restore streambanks and wetlands.
4.6	Seek authorization and funding for development of new water supply sources. Focus funding on critical watersheds, vulnerable water systems, and vulnerable populations
4.7	Develop additional water storage, especially floodwater diversion and storage options Focus funding on critical watersheds, vulnerable water systems, and vulnerable populations. Use LiDAR scans to identify suitable locations for water storage, such as detention/ retention ponds.
4.8	Encourage development of gray water infrastructure.
4.9	Connect vulnerable public water systems to redundant water sources and other supply systems Identify resilient systems to connect to nearby vulnerable systems. DNR records number of "consecutive systems" and "sole-source systems".
4.10	Monitor and review aquifer storage and recovery well analysis and permitting.
4.11	Couple water supply development efforts with infrastructure assessments and improvements in agricultural and rural communities.
4.12	Proactively assist well-owners with maintenance of domestic and industrial wells, including identifying potential well vulnerabilities.
4.13	Expand water treatment capabilities. Focus funding on critical watersheds, vulnerable water systems, and vulnerable populations.
4.14	Continue transitioning to energy sources that do not require water throughput for cooling. Most fossil-fuel and nuclear energy facilities use water for cooling, which has a warm water effluent that might not be permissible during low streamflow. Improved battery capacity may be required for other energy sources.
4.15	Intensify water resource planning efforts in areas where population growth, development, or future climate conditions could stress available water supply in the future.
4.16	Encourage development in areas with sufficient water supply, and/or encourage the use of development fees to fund water supply systems that can reduce the community's risk of drought. Ensure plans account for future conditions (e.g. population growth, increasing temperatures, frequency of drought, etc.). Water suppliers should be an integral partner in local development planning.

4.17	Develop and implement a water conservation and reuse strategy for the State, local governments and/or public and private facilities that incorporates use of green infrastructure, gray water systems and energy production that includes recognition programs.
4.18	Encourage local plumbing codes that promote water efficiency.
4.19	Increase awareness of the cost-effectiveness of replacing aging infrastructure and seek or encourage incentives that reduce water losses through leak detection and distribution system renovation.
5.1	Improve resilience to drought on agricultural land through crop selection and management, soil conservation and soil health, cover crops, perennial groundcover, agroforestry, terraces, windbreaks, conservation cover, tree, pasture planting, grassed waterways, and other soil health and soil conservation measures to retain soil moisture.
5.2	Improve resilience to drought on agricultural land through: irrigation and drainage water management, retention ponds, flow-adjustment valves on field tile systems, expanded irrigation infrastructure & improved irrigation efficiency.
5.3	Improve livestock cooling efficiency.
5.4	Plan for livestock-related transportation during drought at the state level. Note regulations that may inhibit relocation of livestock to non-drought areas, and ease as appropriate when necessary. Note regulations that may inhibit bringing water or feed to drought-stricken areas, and ease as appropriate when necessary.
5.5	Promote among agricultural producers an awareness of climatological trends that suggest droughts may become more common.
5.6	Encourage growth of fields enrolled in the NRCS Conservation Reserve Program that can be used for haying and grazing in USDA-declared drought emergencies.
6.1	Continue work of Iowa Water Resources Coordination Council to facilitate water policies and mitigation funding.
6.2	Encourage the continued establishment of Watershed Management Authorities (WMA) WMA is a mechanism for cities, counties, and soil and water conservation districts to cooperatively engage in watershed planning and management. A WMA may assess and reduce flood risk, assess and improve water quality, monitor federal flood-risk planning and activities, educate residents of the watershed regarding flood risks and water quality, and allocate moneys made available to the authority for purposes of water quality and flood mitigation.
6.3	Undertake water assessment and watershed planning. Utilize NRCS Watershed Surveys and Planning Program and NRCS Watershed Protection and Flood Prevention Program.
6.4	Encourage and support the development and enhancement of local and regional drought management plans. Consider scenarios of long-term droughts and complete loss of water. Integrate drought planning with local and regional water resources planning and hazard mitigation planning. Ensure consideration of future conditions.
6.5	Partner with agricultural and industrial sectors to protect source waters.
6.6	State funding for local water quality protection. The Resource Enhancement and Protection program provides funding to work with soil and water conservation districts to address local water quality protection needs.

3.3.2. Tornado/Windstorm

A. General Description

A tornado is a violent whirling wind characteristically accompanied by a funnel-shaped cloud extending down from a cumulonimbus cloud. It progresses in a narrow, erratic path. Rotating wind speeds can exceed 300 mph and travel across the ground at average speeds of 25-30 mph. A tornado can be a few yards to approximately one mile wide where it touches the ground. An average tornado is a few hundred yards wide. A tornado can move over land for distances ranging from short hops to many miles, causing damage and destruction wherever it descends. The funnel is made visible by the dust that is sucked up and condensation of water droplets in the center of the funnel.



EF Rating	Wind Speeds	Expected Damage
EF-0	65-85 mph	'Minor' damage: shingles blown off or parts of a roof peeled off, damage to gutters/siding, branches broken off trees, shallow rooted trees toppled.
EF-1	86-110 mph	'Moderate' damage: more significant roof damage, windows broken, exterior doors damaged or lost, mobile homes overturned or badly damaged.
EF-2	111-135 mph	'Considerable' damage: roofs torn off well constructed homes, homes shifted off their foundation, mobile homes completely destroyed, large trees snapped or uprooted, cars can be tossed.
EF-3	136-165 mph	'Severe' damage: entire stories of well constructed homes destroyed, significant damage done to large buildings, homes with weak foundations can be blown away, trees begin to lose their bark.
EF-4	166-200 mph	'Extreme' damage: Well constructed homes are leveled, cars are thrown significant distances, top story exterior walls of masonry buildings would likely collapse.
EF-5	> 200 mph	'Massive/incredible' damage: Well constructed homes are swept away, steel-reinforced concrete structures are critically damaged, high-rise buildings sustain severe structural damage, trees are usually completely debarked, stripped of branches and snapped.

The Enhanced Fujita (EF) Scale is used to assign a tornado a rating based on estimated wind speeds and related damage. When tornado-related damage is surveyed, it is compared to a list of damage indicators and degrees of damage which help estimate the range of wind speeds the tornado likely produced. From that, a rating (from EF-0 to EF-5) is assigned. The National Weather Service is the only federal agency with authority to provide official tornado EF Scale ratings. The adjoining chart shows the relationship between structure damage and wind speeds as it pertains to EF tornado ratings.

Windstorms are extreme winds associated with severe winter storms, severe thunderstorms, downbursts, derechos and very steep pressure gradients. Windstorms, other than tornadoes, are experienced in all regions of the United States. Unlike tornadoes, windstorms may have a destructive path that is miles wide and the duration of the event could range from hours to days. These events can produce straight-line winds in excess of 64 knots (73 mph) causing power outages, property damage, impaired visibility, and crop damage. It is often difficult to separate windstorms and tornado damage when winds get above 64 knots. For this reason the SHMT chose in 2013 to combine the formerly separate hazards of tornado and windstorm.

Windstorms occur in every county in Iowa. Historically, windstorm events were associated with severe thunderstorms and blizzards. The National Weather Service (NWS) has developed a windstorm warning system similar to that for events like tornado, winter storm, or thunderstorm. Watches are issued when conditions are favorable for windstorms to develop and they come 12 to 24 hours in advance. Advisories are issued when existing or imminent windstorms cover part or all of the area and pose an inconvenience. Windstorm warnings are issued when existing or imminent high winds cover part or all of the forecast area and pose a threat to life and property.

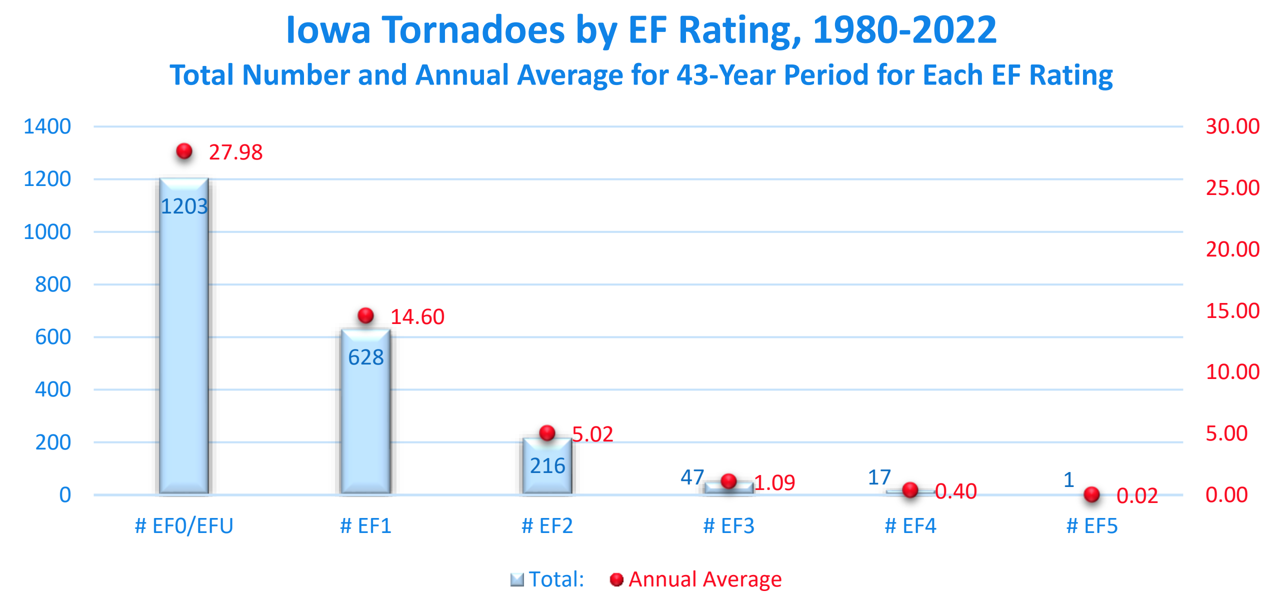
The Beaufort Wind Scale below identifies winds over 73 mph as hurricane-force winds with accompanying damage.

Beaufort Wind Scale. Source: NOAA NWS, https://www.weather.gov/mfl/beaufort.

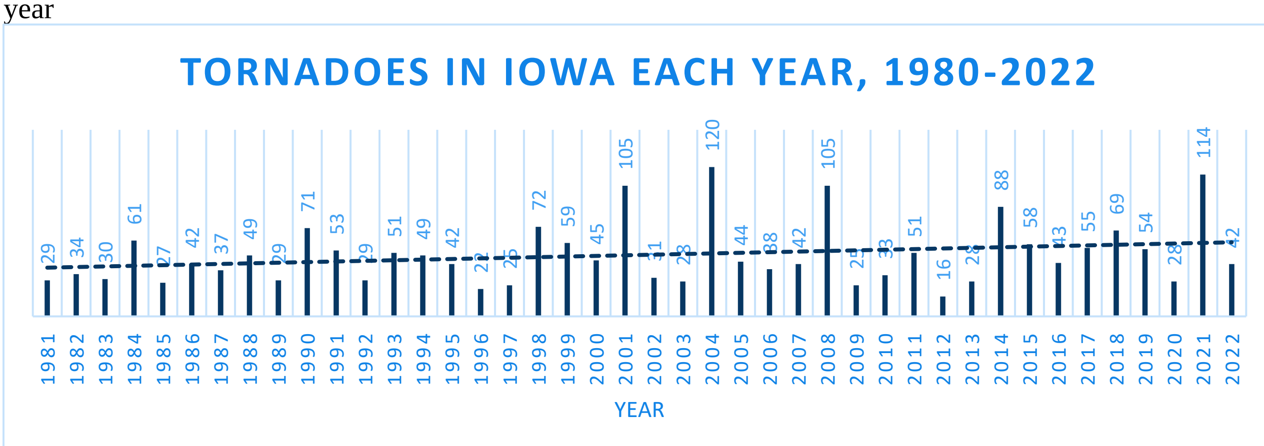
Windspeed in MPH	Description - Visible Condition
0	Calm smoke rises vertically
1 - 4	Light air direction of wind shown by smoke but not by wind vanes
4 - 7	Light breeze wind felt on face; leaves rustle; ordinary wind vane moved by wind
8 - 12	Gentle breeze leaves and small twigs in constant motion; wind extends light flag
13 - 18	Moderate breeze raises dust and loose paper; small branches are moved
19 - 24	Fresh breeze small trees in leaf begin to sway; crested wavelets form on inland water
25 - 31	Strong breeze large branches in motion; telephone wires whistle; umbrellas used with difficulty
32 - 38	Moderate gale whole trees in motion; inconvenience in walking against wind
39 - 46	Fresh gale breaks twigs off trees; generally impedes progress
47 - 54	Strong gale slight structural damage occurs; chimney pots and slates removed
55 - 63	Whole gale trees uprooted; considerable structural damage occurs
64 - 72	Storm very rarely experienced; accompanied by widespread damage
73+	Hurricane-like devastation occurs

B. Previous Occurrences

The extent, or severity, of tornadoes that have occurred in Iowa since 1980 is illustrated in the following chart. It also shows the annual average number of tornadoes of each EF Rating. The next chart shows the

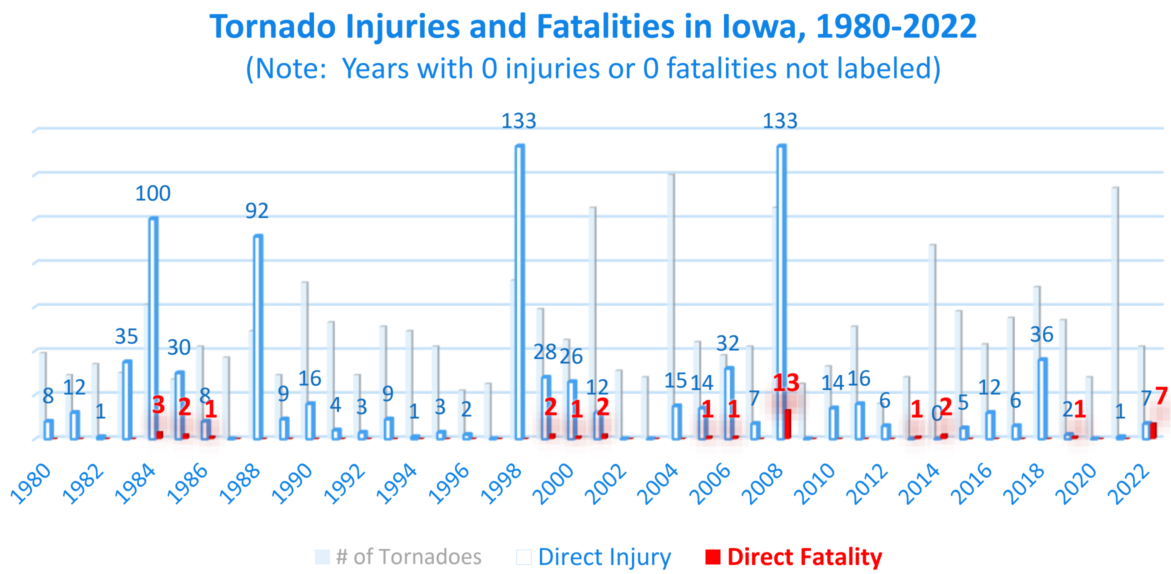


number of tornadoes between 1980 and 2022, inclusive[42]. In that period, Iowa has averaged just over 49 tornadoes per year. Reported tornadoes over that period have trended ever so slightly, though it must be noted that this upward trend may be due in part to better reporting. The average number of days each year



in which tornadoes occur in Iowa is 14.58 (averaged over the years 1980-2022). The following chart shows how many deaths and injuries were caused by tornadoes in that time period.

[42] Sources: Unless otherwise stated, sources for all past tornado information are: NWS report *Iowa Tornado Climatology 1980-2019*, NWS 2020 Iowa Tornado Statistics at https://www.weather.gov/media/dmx/Climate/IowaTorStats2020.pdf, NWS 2021 Iowa Tornado Summary at https://www.weather.gov/dmx/iators2021#:~:text=2021%20Iowa%20Tornado%20Summary,southwest%20side%20of%20Cedar%20Rapids, and NWS 2022 Iowa Tornado Summary at https://www.weather.gov/dmx/iators2022#:~:text=A%20total%20of%20one%20tornado,at%20a%20couple%20of%20farmsteads.



In the five years since the last update of this plan, Iowa has had several major tornado and wind events. In 2022 Iowa was hit by 42 tornadoes, resulting in seven deaths and over $200 million of property damages. The year 2021 saw a very large number of tornadoes in Iowa, with 114, as well as a significant derecho event. Fortunately, there were no tornado deaths that year, although there was an injury. Tornadoes that year resulted in over $17 million of property and crop damages. In 2020 tornadoes struck Iowa on 5 different days, resulting in 28 tornadoes. On March 28, 2020 nine tornadoes touched down. In Oelwein that day multiple apartment buildings sustained significant damage. But August 10, 2020 saw much greater storms and damage, when a derecho ripped across the state and several tornadoes touched down during the August 10th derecho.

In 2019 the tornado season started on May 22 with overnight tornadoes in southwest Iowa, one of which struck a home killing an elderly woman and injuring her husband. In all there were 54 tornadoes that year, causing over $3 million in property damage. A total of 69 tornadoes occurred in Iowa in 2018. The most significant were two EF3 tornadoes. One EF3 hit the Vermeer manufacturing plant in Pella, resulting in 13 injuries. The other made a path of destruction through Marshalltown, cutting through the middle of the business district, and produced 22 injuries and over $200 million of damage[43].

Other large tornado and wind events of the last few years are described in more detail below.

April 12, 2022 Tornado Outbreak
(From NWS Des Moines office[1])
In Iowa, storms developed in the early evening and continued in a line across the area through the night. Early storms produced a number of tornadoes, especially across parts of western Iowa with damage reported in Pocahontas, Humboldt, and southern Hancock counties. Information there and in a few other location is still being analyzed to determine tornado occurrence and subsequent size and strength. In addition, up to tennis ball sized hail was reported.

[43] https://www.weather.gov/dmx/iators2018

March 5, 2022 Tornado Outbreak

(From NWS Des Moines office[44])

Three supercells swept across Iowa, producing several tornadoes. Two supercells in southern Iowa produced three tornadoes. Meanwhile, a single long track supercell produced multiple tornadoes from the southwest corner of Iowa all the way through central Iowa and into east central Iowa. The largest tornado moved across Madison, Warren, Polk, and Jasper counties for nearly 70 miles and at its peak produced winds of nearly 170 mph. This is the first EF-4 tornado in Iowa since October 4, 2013 which occurred in Woodbury and Cherokee Counties. This is second longest tornado in Iowa since 1980, behind the longest occurring on June 7, 1984 at a length of 117 miles across southern Iowa.

December 15, 2021 Derecho and Tornado Outbreak

(From NWS Des Moines office[1])

December 15, 2021 was an unprecedented and historic event for the state of Iowa. It featured the first derecho in December anywhere in the United States and the first Moderate Risk (Level 4 or 5) of severe thunderstorms issued by the NWS Storm Prediction Center in December in Iowa. Officially, it set the new record for most tornadoes in Iowa and the most EF-2/F-2 or stronger tornadoes in a single day in Iowa since 1950. . . . There were 63 confirmed tornadoes that occurred in Iowa with 21 of those tornadoes being rated EF-2. . . . Prior to this event, a total of 5 tornadoes had occurred in Iowa in December since 1950 with all of them in southeastern Iowa. To have over 10 times that many tornadoes in a single day is unprecedented in any month, let alone the month of December!

Numerous straight line wind gusts were also associated with these thunderstorms, some in excess of 80 mph. During the event, nearly the entire state of Iowa was under a Severe Thunderstorm Warning at some point. Audubon reported the highest gust in Iowa at 88 mph. This storm also met the criteria for a “derecho", which makes it the first derecho on record in the month of December anywhere in the United States.

After the line of storms had passed, numerous strong, non-thunderstorm wind gusts over 70 mph occurred overnight. The top three non-thunderstorm wind gusts were 83 mph in Decatur City, 81 mph in Marshalltown, and 80 mph in Johnston. The Des Moines International Airport recorded a 74 mph non-thunderstorm wind gust, which is the highest non-thunderstorm wind gust at this location since 1970.

[44] Retrieved on 21 February 2023 from https://www.weather.gov/dmx/March5th2022Tornadoes

August 10, 2020 Derecho and Tornado Outbreak

(From NWS special storymap report[45])

A long-lived line of severe storms known as a "derecho" produced severe wind damage across portions of South Dakota, Nebraska, Iowa, Illinois, Wisconsin, Indiana, Michigan, and Ohio on Monday, August 10, 2020. A large area from central Iowa to north central Illinois experienced wind gusts of 70-80 mph, with maximum wind gusts of over 100 mph in a few isolated areas. The storm system also produced 26 weak tornadoes (rated EF-0 to EF-1 with wind speeds of 65 to 110 mph) in Iowa, Wisconsin, Illinois, and Indiana, although damage from the tornadoes was similar in magnitude to that caused by the straight-line winds covering a much larger area.

This particularly significant derecho event caused widespread power outages and downed trees, damaged structures, toppled semi-trailers, and flatted crops over a large area. . . . The most extreme damaging wind gusts (those estimated over 100 mph) occurred in portions of central and eastern Iowa as well a few isolated locations along the Iowa/Illinois border and in Illinois. Wind gusts in excess of 100 mph were estimated to have covered an area of at least 2,000 square miles, which is home to over 300 thousand people. The strongest estimated wind speeds in the vicinity of Cedar Rapids, Iowa, were among the highest wind speeds ever recorded during a derecho event, peaking at about 140 mph. . . .

A corridor of significant straight-line winds (80 to 100 mph) began to the east of Denison, and continued toward Ames and Des Moines. Wind gusts were severe enough to not only cause widespread damage to trees and powerlines, but to also damage structures and crops. . . . Three tornadoes also occurred near Marshalltown, which, due to the more severe and more extensive damage from straight-line wind gusts, had to be determined from satellite and drone imagery. . . . The area of extreme winds near Marshalltown, Iowa maintained strength during the early afternoon and strengthened as it moved east.

Numerous instances of damaged or destroyed outbuildings, barns, grain bins, homes, mobile homes, apartment buildings, businesses, trees, and power poles were reported. . . .

The maximum estimated wind gusts from the entire derecho occurred in the Cedar Rapids area. Several homes, apartment complexes, and businesses sustained damage consistent with 130 to 140 mph winds. One person was killed and numerous injuries were reported. Notably, damaging winds (greater than 60 mph) continued for over an hour in some locations, much longer than the typical 10 to 20 minute duration of winds during severe thunderstorms. Widespread, long-duration power outages occurred across the area, with some parts of Cedar Rapids without power for about two weeks. More than half of the trees in Cedar Rapids were lost.

A corridor of particularly extreme winds - peak wind gusts reaching 120 mph or greater - began in Benton County, Iowa, and then moved east into Cedar Rapids, Iowa. Near Wiley Boulevard and Wilson Avenue, winds estimated at about 140 mph removed the roof and multiple exterior walls of an apartment building. Nearby, multiple other residences sustained damage to rooftops and some walls, and a small strip mall was significantly damaged. . . . Just northeast of Marion near IA-13 and Radio Road, peak wind gusts estimated at about 130 mph toppled the radio transmitter for WMT. . . . In the immediate vicinity of Clinton, Iowa, a narrow corridor of more intense winds (100 to 120 mph) occurred. A radio transmission tower collapsed in that area due to winds estimated around 130 mph.

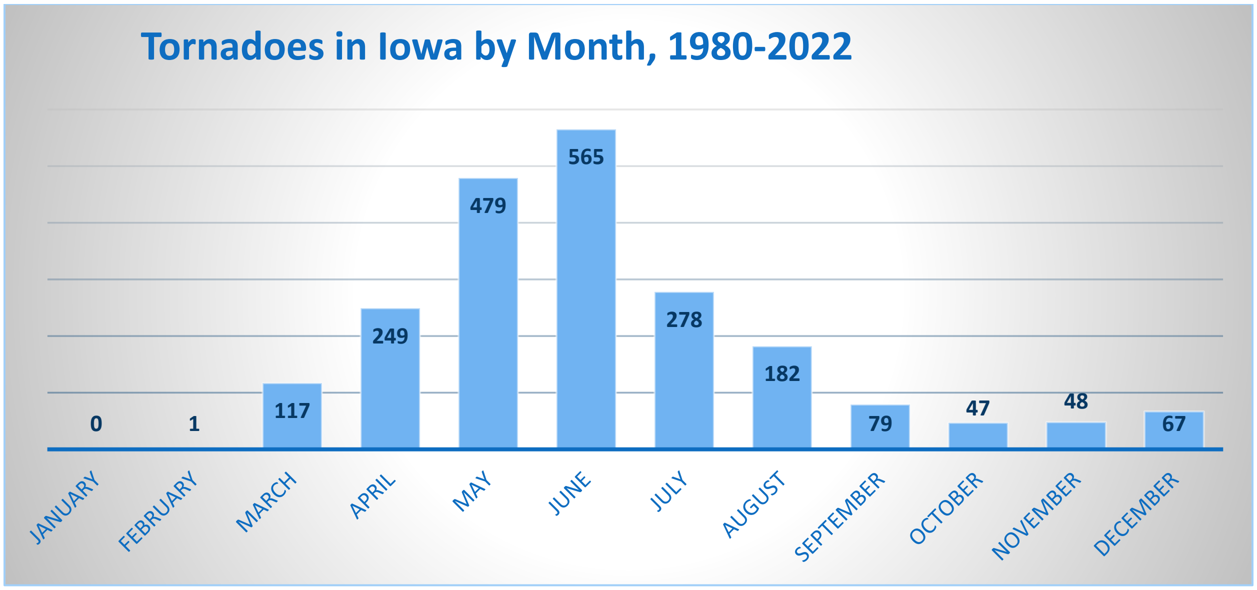
Over this time period, the wide corridor of flattened corn and soybean crops continued to be severe enough to be visible on satellite imagery. Power outages were . . . visible from space at night.

Tornadoes can occur any month of the year in Iowa, but they are most prevalent in summer and late spring, with May and June being the prime months. As stated in the NOAA National Weather Service (NWS) report *Iowa Tornado Climatology 1980-2019*[46], these "two months have prime conditions for

[45] Retrieved on 21 February 2023 from https://storymaps.arcgis.com/stories/f98352e2153b4865b99ba53b86021b65

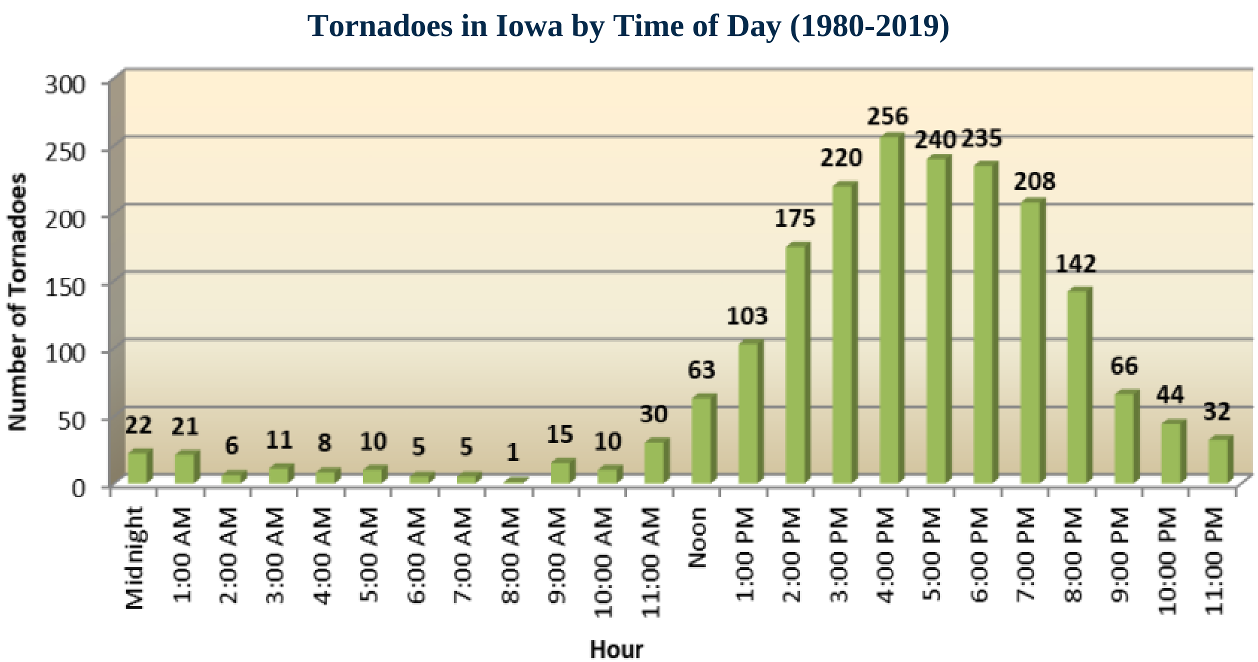
[46] Prepared by Craig Cogil. See https://www.weather.gov/media/dmx/Climate/IowaTorClimatologyFinal2019.pdf

tornadoes including warm temperatures, ample moisture, and relatively strong winds at different levels in the atmosphere (wind shear)". The chart below shows the number of tornadoes that occurred in Iowa from 1980 through the end of the 2022. The chart shows that no tornadoes occurred in January in Iowa in that period, but Iowa does experience a January tornado every so often. In fact, two tornadoes were reported in eastern Iowa on January 16, 2023.[47]



As with certain months being more favorable than others for tornadoes, the same applies to the time of day. As illustrated in the chart below from *Iowa Tornado Climatology 1980-2019*, peak activity for tornadoes in Iowa is from mid-afternoon until around sunset.

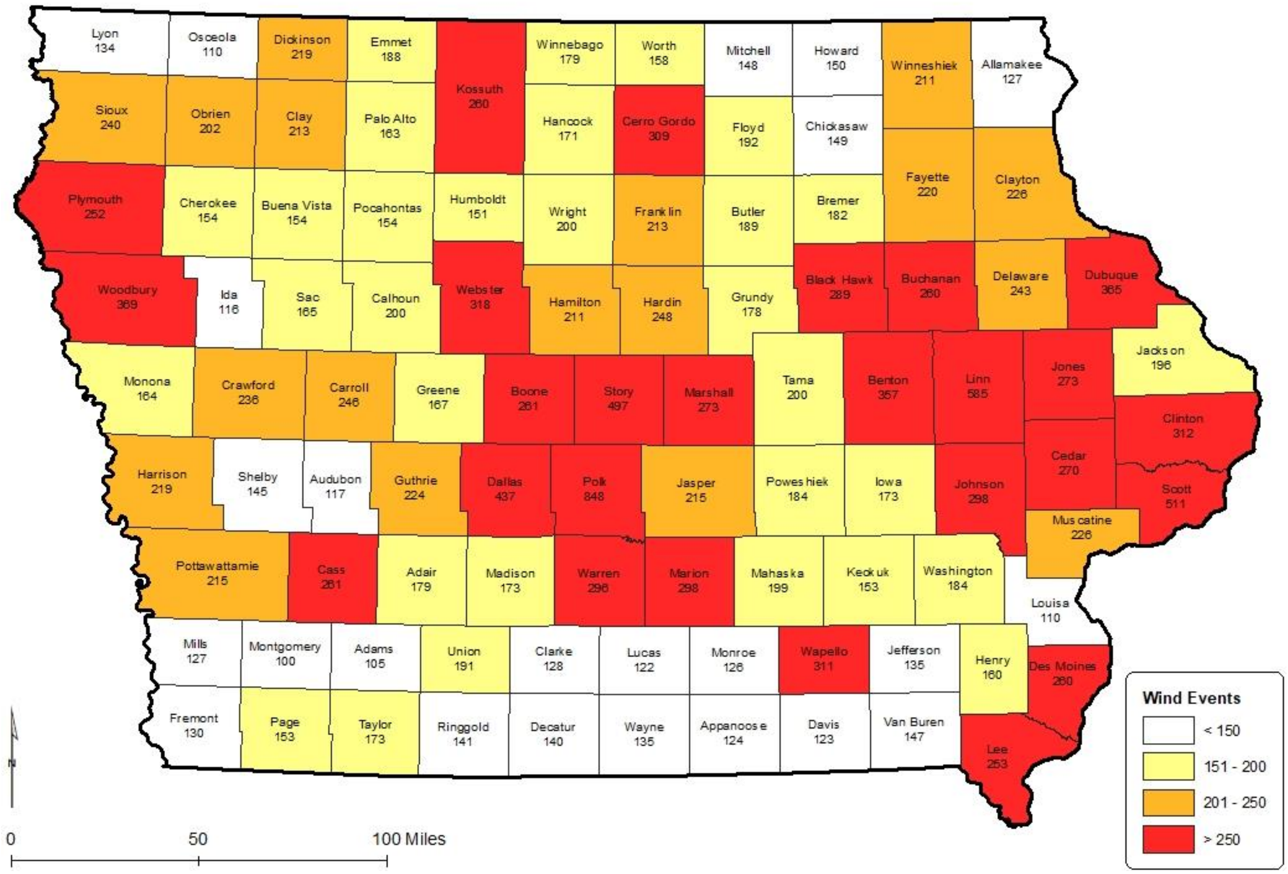
[47] https://www.kwqc.com/2023/01/23/tornadoes-january-how-often-do-they-occur-iowa-illinois/



Since 1968, Iowa has received 24 Presidential Disaster Declarations that include tornadoes in the description. Several of those declared disasters also included other wind events, besides tornadoes. For instance, the declared disaster for the events of December 15, 2021, included both a derecho and tornadoes. In addition, Iowa received a disaster declaration for the August 10, 2020 storm that produced a record-setting derecho.

In the five-year period between December 2017 and November 2022, Iowa experienced more than 400 wind events (compiled from the following windstorm events tracked in the NCEI Storm Events Database: thunderstorm wind, straight-line high or strong winds, and funnel clouds, which are tornado-like events which do not have contact with the ground). Property damage from those events were estimated by NCEI sources to be $12,245,000 with crop damages over $700,000. These events caused 3 fatalities (and at least one indirectly). They also directly resulted in 122 injuries and at least 100 indirectly. The map below shows the number of wind events each county has had since 1955.

Wind Events in Iowa Counties Since 1955. Source: NCEI Storm Events Database[48]



C. Location, Probability, and Intensity

One may infer from looking at historical numbers of reported tornadoes that the number of tornadoes each year has increased and therefore the probability of one is increasing. However, according to Roger Edwards, Lead Forecaster of the Operations Branch at the NOAA Storm Prediction Center, the number of tornadoes may not actually be increasing, just the number of tornado *reports:*

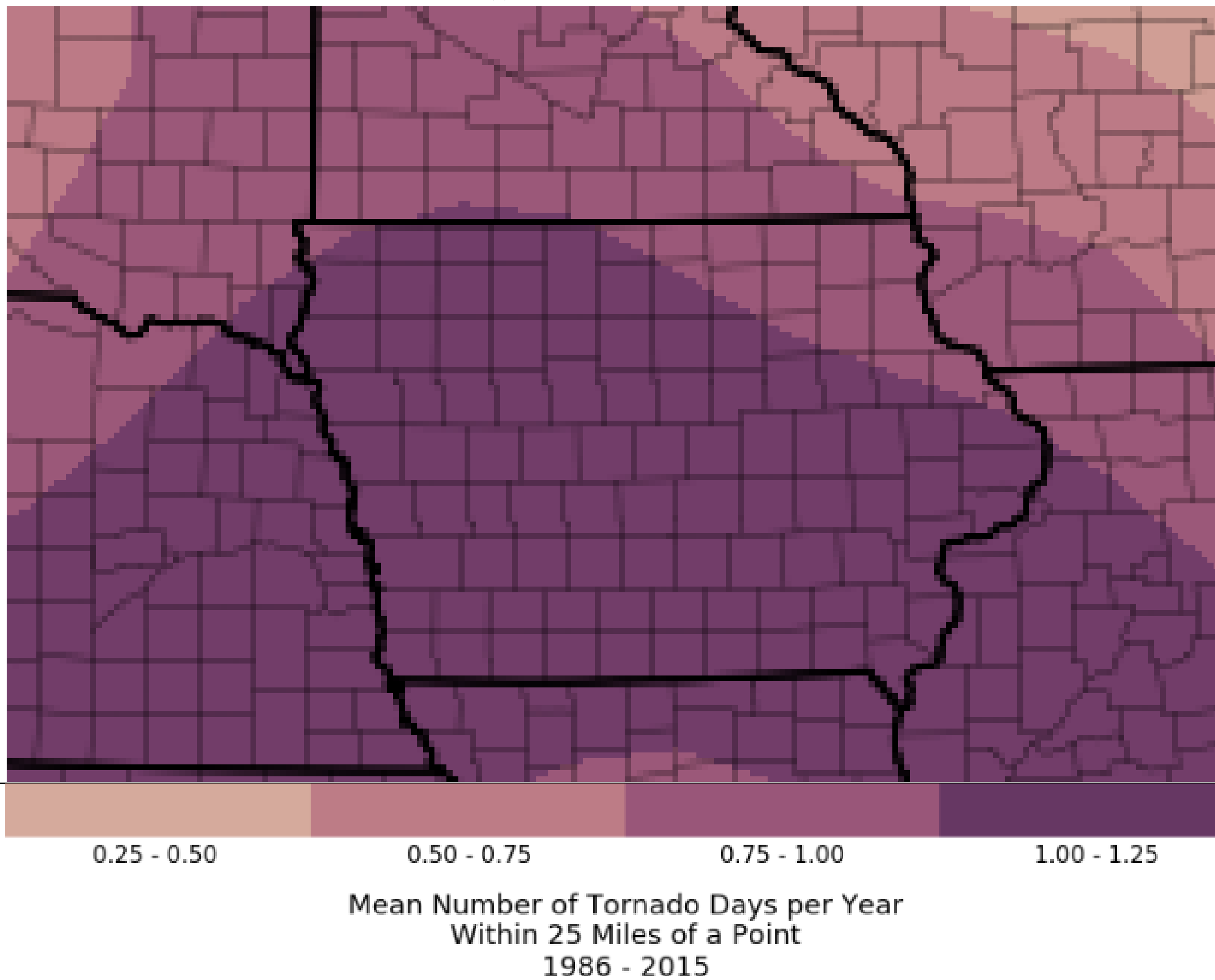
> Tornado *reports* have increased, especially around the installation of the NEXRAD Doppler radar system in the mid 1990s. This doesn't mean that actual tornado occurrence has gone up, however. The increase in tornado numbers is almost entirely in weak (EF0-EF1) events that are being reported far more often today due to a combination of better detection, greater media coverage, aggressive warning verification efforts, storm spotting, storm chasing, more developmental sprawl (damage targets), more people, and better documentation with cameras (including cell phones) than ever. Modern averages of roughly 1200 per year nationwide probably are as close to the truth as we've ever seen. Another few decades of well-documented tornadoes will tell us more. To compare tornado counts before Doppler radars, we have to either adjust historical trends

[48] Data from https://www.ncdc.noaa.gov/stormevents/. Number with county is number of events for county for 1955-November 2022 for these event types: thunderstorm wind, straight-line high or strong winds, and funnel clouds.

> statistically to account for the unreported weak tornadoes of before, or look only at strong to violent (EF2-EF5) tornadoes, whose records are much better documented and more stable. When we do that, very little overall change has occurred since the 1950s. Here is a graph of raw and adjusted trends through 2015. About the only thing we can infer with good certainty from this is that the year-to-year *variability* seems to be swinging more wildly up and down since 2000, even though the averages are essentially staying flat. [from http://www.spc.noaa.gov/faq/tornado/]

With that in mind, it may be good to both look at the probability of *any* tornado in Iowa AND then examine the probability of *significant* tornadoes (meaning EF-2 or higher). First, information that illustrates the probability of *any* tornado in Iowa is shown in the next map figure. It shows that most places in Iowa have had the roughly the same rate of reported tornadoes (of any magnitude) over the last 40 or so years, though northeast Iowa has had a somewhat lower rate of reported occurrences.

Illustrating Probability of Tornado Occurrence (any strength).
Source NWS Storm Prediction Center[49]

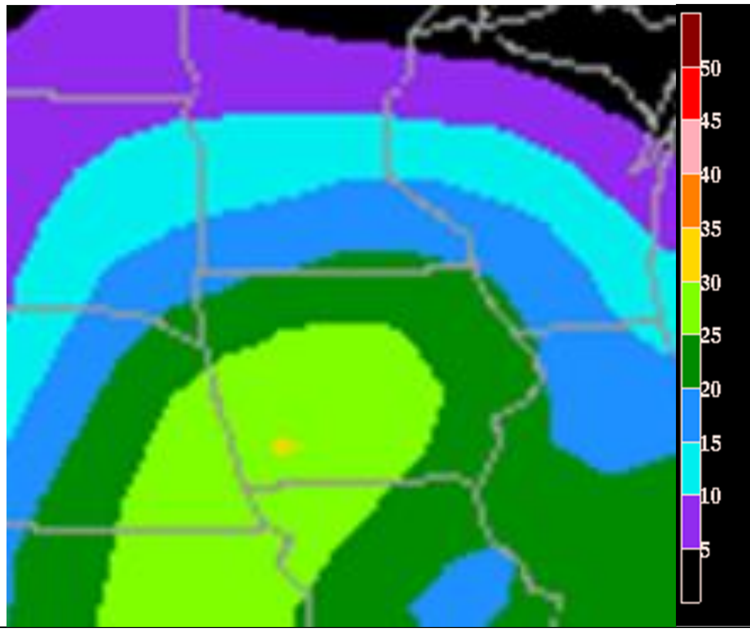


[49] https://www.spc.noaa.gov/wcm/climo/alltorn.png. For more 30-year Severe Weather Climatology from the NWS Storm Prediction Center see https://www.spc.noaa.gov/wcm/#30yrclimo .

The next two maps illustrate the probability of *significant* tornadoes. The map figures are very similar to each other. They differ in that:

1. The first map is based on an earlier time period (1921-1995; the following map is based on 1986-2015).
2. The map from earlier data shows number of tornadoes that were F2 or higher, whereas the map from the later time period has tornadoes of the ***Enhanced*** Fujita scale **E**F2 or higher.
3. The legends for each are slightly different: the first shows number of significant tornadoes per *century* whereas the second maps shows number of significant tornadoes per *decade.*

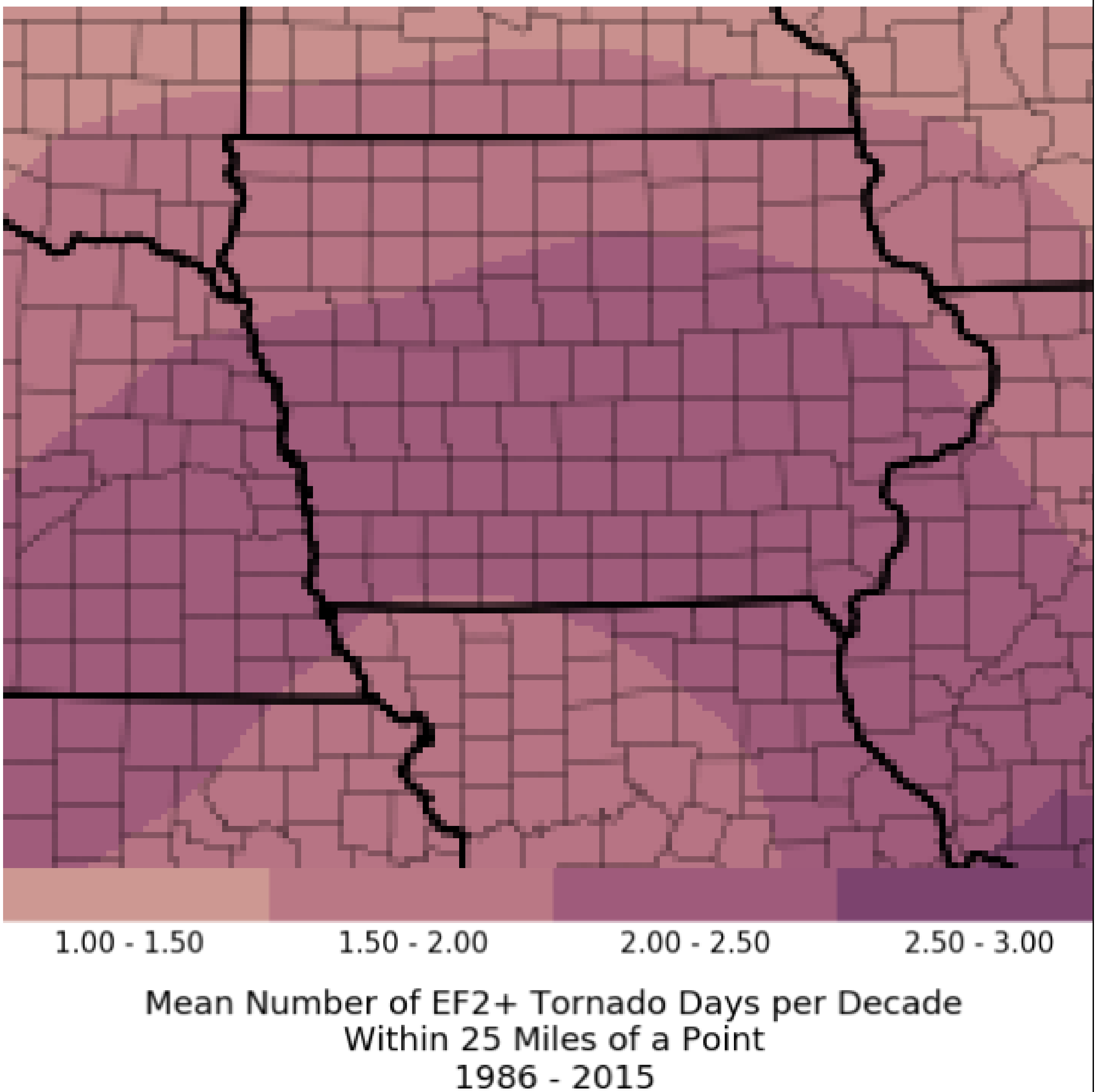
Significant (F2 or greater) Tornado Days per Century (1921-1995).
Source: NOAA.



Looking closely at the two maps, it appears that the number of significant tornadoes per decade (or per century) has declined: Over the period 1921-1995 there were 2 to 3 significant tornadoes per decade in most Iowa locations, whereas over the period 1986-2015 there were 1.5 to 2.5 significant tornadoes per decade within 25 miles of any location in Iowa. To restate this in terms of probability, these datasets appear to show that the probability in any year for anywhere in Iowa to experience a significant tornado within 25 miles is only 0.15 to 0.3 percent.

As far as which areas of Iowa have a higher probability of significant tornadoes, the map based on recent data appears to show that northern Iowa has less likelihood of tornado occurrences than the rest of the state. The other map appears to show that southwest and central Iowa are more likely to experience significant tornadoes than the rest of the state. Regardless, the difference in probability or historical occurrence between different areas of Iowa is only about 0.1 percent. In other words, for all intents and purposes, no part of the state is significantly more susceptible to tornadoes than another part. Every part of the state needs to understand and prepare for the risk.

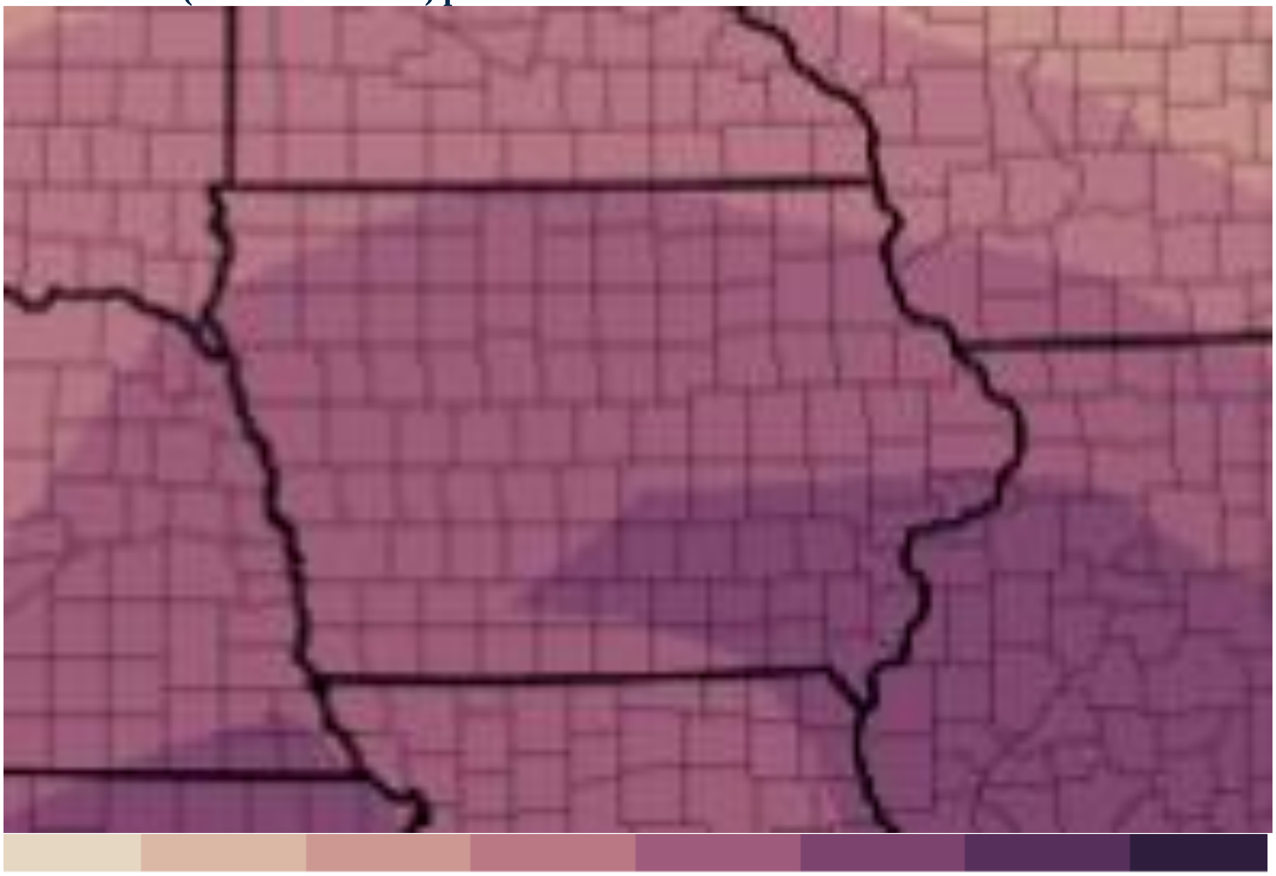
Illustrating Probability of Significant Tornado Events. Source NWS Storm Prediction Center (https://www.spc.noaa.gov/wcm/climo/sigtorn.png)



Wind

The map below illustrates the probability of wind in various parts of Iowa and the United States by showing the number of wind days per year averaged over the years 1986 to 2015. If the trends from 1986 to 2015 are any indication of future probability, then the map can be used to illustrate where high winds (over 50 knots) would be expected and how often: southeast Iowa would be expected to have more wind days per year (5-6) while northwest Iowa fewer (3-4 per year). As with tornadoes, every part of the state needs to understand and prepare for the risks due to high wind.

Illustrating Probability of Wind, Reflected by Wind Days (50 knots or more) per Year. Source: NWS Storm Prediction Center[50]



The following map is similar but for derechos. It shows the approximate number of times "moderate and high intensity" (MH) derechos affected points in the Midwest during the years 1980 through 2001[51]. Areas affected by three or more derecho events are shaded in yellow, orange, and red. Given that the map depicts the number of events that occurred over a 22-year period, dividing the values by 22 allows one to estimate the annual or seasonal frequency of derechos. By doing so, the annual frequency for MH derechos in Iowa averages just under one per year. The map shows that southwest Iowa experiences derechos less frequently than the rest of the state (assuming the period of record and data is accepted as significant enough to calculate probability/frequency).

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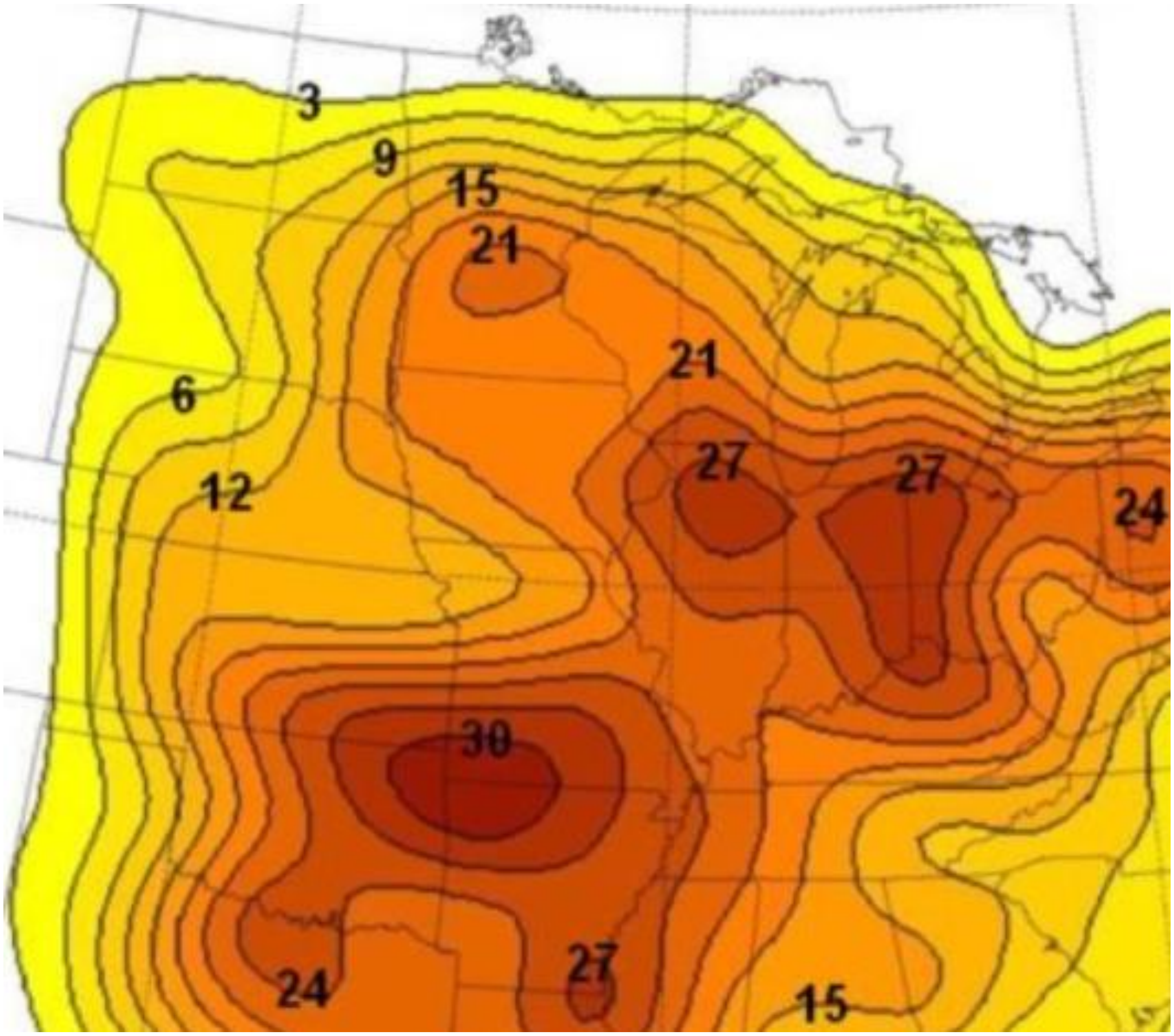
[50] https://www.spc.noaa.gov/wcm/climo/allwind.png

[51] Source: Coniglio, M.C., and D. J. Stensrud, 2004: Interpreting the climatology of derechos. Weather Forecasting, 19, 595-605. See https://www.spc.noaa.gov/misc/AbtDerechos/climatologypage.htm.

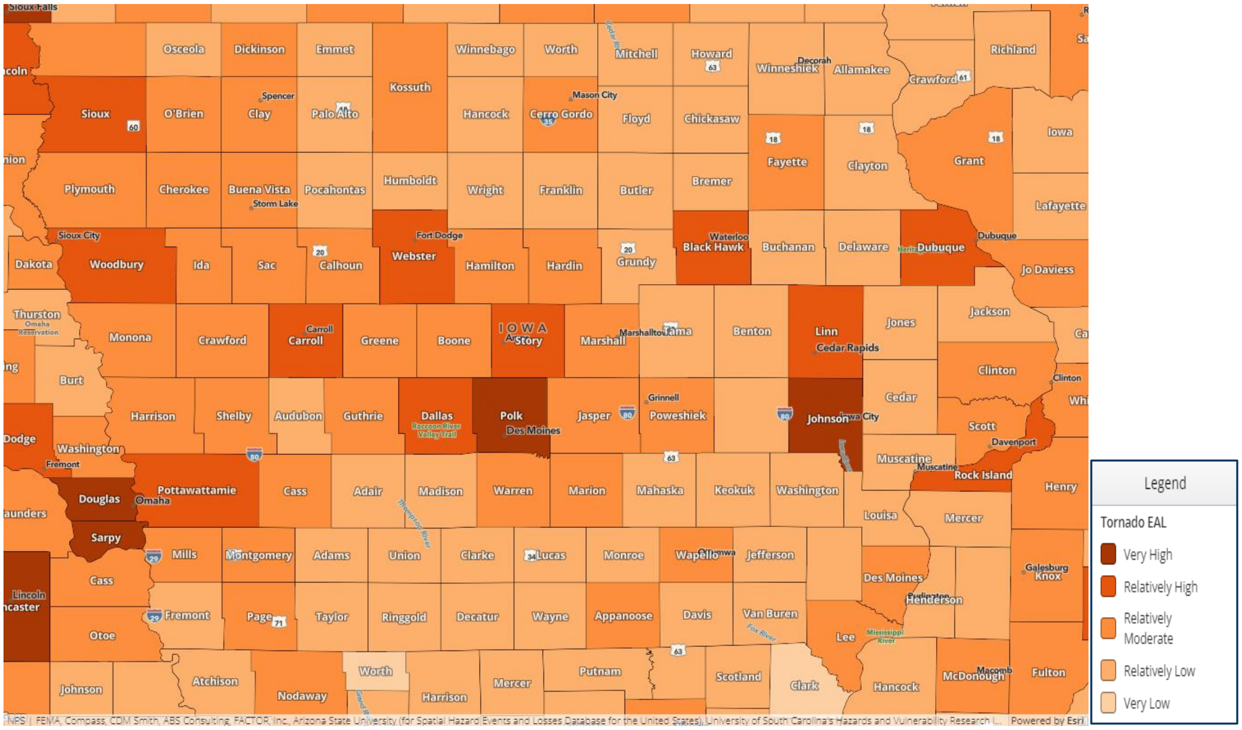


D. Summary of Vulnerability and Problem, and Identification of Possible Actions to Mitigate Problem

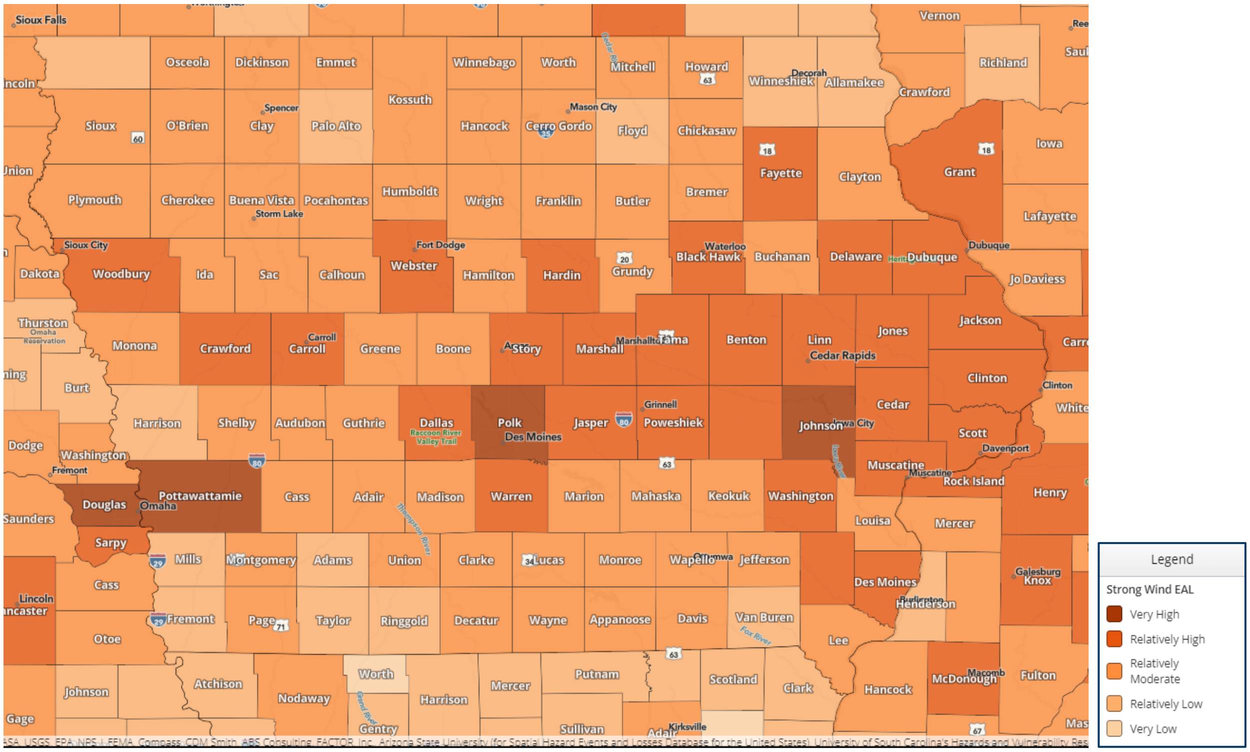
The maps below summarize tornado and strong wind vulnerability based on analyses from FEMA's National Risk Index (NRI). They present the results of analyses to estimate expected annual loss (EAL) from tornadoes, in the first map, and strong wind events in the second map. EAL is calculated by multiplying exposure by annualized frequency and historic loss ratio (details about NRI's methodology may be found in *National Risk Index Technical Documentation, November 2021*[52]*).* To find the counties most vulnerable to **both** tornado and strong wind combined, one need only add the Tornado EAL with the Strong Wind EAL for each county. The table below shows the counties that have the highest EALs for these two wind hazards combined.

[52] http://www.fema.gov/sites/default/files/documents/fema_national-risk-index_technical-documentation.pdf

Tornado Expected Annual Loss (EAL) for Iowa Counties. Source: FEMA's NRI (hazards.fema.gov/nri/map)



Strong Wind EAL for Iowa Counties. Source: FEMA's NRI (hazards.fema.gov/nri/map)



Counties Most Vulnerable to Tornado and Wind Events (per NRI Expected Annual Loss figures)			
County	**Strong Wind EAL**	**Tornado EAL**	**Combined EALs**
Polk	$ 9,909,779	$ 14,941,129	**$ 24,850,908**
Johnson	$ 6,922,256	$ 16,502,750	**$ 23,425,006**
Pottawattamie	$ 2,721,694	$ 7,075,705	**$ 9,797,399**
Linn County	$ 2,147,861	$ 7,519,480	**$ 9,667,342**
Woodbury	$ 1,430,088	$ 7,822,581	**$ 9,252,669**
Black Hawk	$ 2,362,968	$ 3,960,424	**$ 6,323,392**
Webster	$ 737,606	$ 4,549,788	**$ 5,287,394**
Story	$ 827,714	$ 4,280,529	**$ 5,108,243**
Dubuque	$ 1,161,508	$ 3,223,518	**$ 4,385,026**
Scott	$ 2,284,674	$ 1,967,117	**$ 4,251,791**
Dallas	$ 1,162,657	$ 2,879,182	**$ 4,041,838**
Entire State (all 99 counties)	$ 79,527,714	$146,457,930	**$ 225,985,643**

The counties with the highest EAL have the larger cities of Iowa. Cities may face the greatest vulnerability because of their concentration of buildings, population, and utilities. Then again, rural communities face the potential of severe economic impact because there is less economic diversity than in a large city, and a tornado could immediately knock out the economic legs upon which the community stands.

While the potential is great for economic and structural devastation with a tornado and high winds, the greatest loss that can happen is to human life. As such, the most important mitigation actions have to do with preserving life and preventing injuries. These are some possible actions that focus on mitigation of the most serious impacts of tornadoes and strong winds in Iowa:

1. Construction of safe rooms
2. Installation or improvement of tornado/wind sirens.
3. Electrical utility retrofit/hardening
4. Creation and disbursement of educational materials to improve awareness of tornado and wind event risks and ways to prevent or reduce impacts
5. Promotion of NOAA all-hazards weather radios
6. Installation of backup power generators at critical facilities
7. Adoption and better enforcement of, or otherwise encourage the use of, building standards in individual jurisdictions and/or statewide so that buildings can better withstand high winds, including standards such as these[53]:
    a. The International Residential Code (IRC) and associated wind loading provisions in ASCE 7 for one-and two-family dwellings (the IRC and the wind loading provisions of ASCE 7 provide a reasonable level of safety, and are not focused on property protection, life-safety protection, or preventing all damage during extreme windstorms).
    b. Use and correct installation of higher than code-minimum, wind-rated asphalt shingles. To reduce wind damage to asphalt shingles, FEMA recommends the use of Class F rated shingles as determined by ASTM International (ASTM) D3161 or Class H rated shingles as determined by ASTM D7158.1. Also require or encourage a sealed roof deck designed to stay in place and keep water from entering the house if the primary roof covering is damaged or lost due to high winds.
    c. Require or encourage use of higher than code-minimum, wind-rated tile or metal roofing and the correct installation of such.
    d. Require or encourage use of roof sheathing that is at least 7/16" inch thick, attached with at least 8d common nails or 8d ring shank nails spaced every 6 inches at panel edges and intermediate supports.
    e. For solar roof panels, require or encourage solar panels to be designed and installed with:
        i. Sufficient uplift resistance to meet the calculated wind loads.
        ii. Panels and rail/rack systems that have UL 1703, Standard for Flat-Plate Photovoltaic Modules and Panels, and UL 2703, Standard for Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use with Flat-Plate Photovoltaic Modules and Panels listing.
        iii. Double-nutting panel clamp bolts.
        iv. All bolted connections made with a calibrated torque wrench.
        v. Rigid solar panels over metal standing seam roofs using external seam clamps. External seam clamps are required at every roof deck seam.
        vi. Flexible solar panel modules that are FM Approved for hail or meet FM 4476, Flexible Photovoltaic Modules, and include a Severe Hail rating.

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[53] For more details, see https://www.fema.gov/sites/default/files/documents/fema_improving-windstorm-resilience-fact-sheet_022023.pdf

vii. Rigid solar panel modules that are FM Approved for hail or meet FM 4478, Roof Mounted Rigid Photovoltaic Modules, and include a Class 4 rating.

f. Where vinyl siding is used, require or encourage that it meet the requirements of the standard specification for Rigid Poly/Vinyl Chloride (PVC) Siding from the ASTM D3679 and that it is attached per International Residential Code (IRC) Section R703.11.1 and manufacturer installation guidelines.

g. Where fiber-cement siding is used, require or encourage that siding sections be face nailed through the overlapping board instead of blind nailed, and that pieces of siding end at a stud location, allowing for nails to be installed on each side of the siding butt joint.

h. Where brick veneer is used, require or encourage that it be installed properly to resist high winds (see FEMA P-499, Technical Fact Sheet 5.4, Attachment of Brick Veneer in High-Wind Regions https://www.fema.gov/sites/default/files/2020-08/fema499_2010_edition.pdf).

i. Encourage the use of impact-resistant glazing that complies with ASTM E19966 and ASTM E18867, the Large Missile D.

j. For garage doors on attached garages, require or encourage doors that are tested in accordance with either ASTM E33010 or American National Standards Institute (ANSI) / Door & Access Systems Manufacturers' Association (DASMA) 108 and meet the pass/fail criteria of ANSI/DASMA 108. Also require or encourage that the fastening of the door track is in accordance with DASMA TDS 156 and 161. (See IBHS FORTIFIED Technical Bulleting FH 2021-01, Garage Door Requirements in the 2020 FORTIFIED Home Standard (https://FORTIFIEDhome.org/wp-content/uploads/2021-01_technical-bulletin_garage-doorrequirements.pdf?v=1672845619105)

k. Encourage installation, including retrofitting, of soffits so that they have a minimum pressure rating of +22 psf/-30 psf (for a soffit height of 15 feet) to +26 psf/-35psf (for a soffit height of 35 feet). See FEMA P-804 for recommended soffit retrofits.

l. Require or encourage each roof truss and rafter be attached to the framed wall's double top plate with a connector designed to resist the loads for the corresponding roof truss or rafter span and spacing.

m. Require or encourage wall sheathing is to be nailed to both the studs and top plate.

n. Require or encourage the sill plate, or bottom plate, be attached to the masonry or concrete foundation with anchor bolts and minimum 0.229-inch x 3-inch x 3-inch washers.

o. Require or encourage wood wall sheathing panels extend upward from the first-floor walls and downward from the second-floor walls and nailed to the rim/band joist; and metal connectors extend from lower floor wall framing, across the floor framing above, and to the upper floor wall framing.

p. Where there is a platform gable end wall more than 3 feet tall, require or encourage the use of structural sheathing and sufficient connection of the gable end to the wall framing below (see IBHS 2020 Fortified Home Standard (https://fortifiedhome.org/wp-content/uploads/2020-FORTIFIED-HomeStandard.pdf?v=1666886854360).

3.3.3. Flooding (Flash and Riverine)

A. General Description

While the hazards of flash flooding and riverine flooding are often designated separately, they will be discussed together here because often people will just refer to "flooding", especially when referring to the damage they cause, and no distinction is made whether the flood event was riverine or flash. In fact, FEMA disaster declarations usually do not designate in the title of a disaster whether flooding was flash or riverine.

A flash flood is an event that occurs with little or no warning where water levels rise at an extremely fast rate. Flash flooding results from intense rainfall over a brief period, sometimes combined with rapid snowmelt, ice jam release, frozen ground, saturated soil, or impermeable surfaces. Most flash flooding is caused by slow-moving thunderstorms or thunderstorms repeatedly moving over the same area. Even with information on soil saturation and predicted rainfalls, flash floods can still catch people by surprise. Flash flooding is an extremely dangerous form of flooding which can reach full peak in only a few minutes and allows little or no time for protective measures to be taken by those in its path. Flash flood waters move at very fast speeds and can move boulders, tear out trees, scour channels, destroy buildings, and obliterate bridges. Flash flooding often results in higher loss of life, both human and animal, than slower-developing river and stream flooding.

A riverine flood is a temporary condition of partial or complete inundation of normally dry land areas from the overflow of stream banks. Flooding results when the flow of water is greater than the normal carrying capacity of the stream channel. Floodwaters can be extremely dangerous; the force of 6 inches of swiftly moving water can knock people off their feet and 2 feet of water can float a car. Floods can be slow or fast-rising but generally develop over a period of days. Flooding is a natural and expected phenomenon that occurs annually, usually restricted to specific streams, rivers, or watershed areas.

Riverine flooding can also be caused by ice jams. Ice jam flooding generally occurs when warm weather and rain break up frozen rivers or any time there is a rapid cycle of freezing and thawing. The broken ice floats downriver until it is blocked by an obstruction such as a bridge or shallow area, where an ice jam forms. The ice jam then blocks the channel and causes flooding upstream.

B. Previous Occurrences

Floods are the most common and widespread of all natural disasters in Iowa. In the last 30 years, every county in the state of Iowa received at least five Presidential Disaster Declarations that included flooding. The years with the highest number of county declarations are 1993, 2005, 2008[54] and 2019.

Since 1953, Iowa has received 46 Presidential Disaster Declarations for major disasters related to flooding. Note: FEMA's data visualization web tool says there have been only 29, but that appears to only count the disasters for which "flood" was among the first words in the description of the disaster – there were several other disasters that were declared for flood <u>and</u> some other hazard event.

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[54] A. Arenas Amado, I. Brenner, W.F. Krajewski, L.J. Weber (2018). *Three Decades of Flood in Iowa*. (p.6).

In Iowa, as much as 21 inches of rain has fallen in a 24-hour period. Just over five years ago, in 2018, the City of Ankeny saw 10 inches fall in one night. A year before that the city of Sumner received more than 15 inches of rain within a 30-hour period. These events resulted in Presidential Disaster Declarations due to widespread personal and physical property losses. The most recent Presidential Disaster Declaration for flooding in Iowa occurred in 2019. In March of that year flooding occurred from rapid snowmelt and heavy rainfall on top of already saturated soils. It closed Interstate 29 for nearly two months and caused an estimated $2 billion in damages.[55] In Eastern Iowa, the Quad Cities spent 96 days with the Mississippi above flood stage levels. In Burlington, the Mississippi rose above its banks for more than 104 days, surpassing its 1993 record.[56] Most of the tributaries to the Mississippi River in Iowa saw moderate to major flooding due to snowmelt, frozen ground, ice jams, saturated soils, and rainfall from March 9th-12th and again in late April/early May. The higher crests occurred on the Skunk, English, Cedar, Wapsipinicon, and Maquoketa Rivers. Most of these rivers crested during the 2nd and 3rd weeks of March and again in early May. Major flooding also occurred on the mainstem Mississippi where all sites saw one of their top 5 crests on record. The flood crest at Rock Island Lock and Dam reached a new record of 22.70 ft. This flooding had numerous impacts, with many roads, businesses, homes, and people affected.[57] On April 30 of 2019 the Mississippi River broke through a temporary flood wall in Davenport, "letting the water rush into 2nd Street before it surged into the wider downtown, wreaking havoc on streets, cars, and local businesses." Nobody was hurt, but about two dozen people needed to be rescued.[58] Three blocks downtown went underwater, causing several businesses to close with some never to open again.[59]

As mentioned with the 2019 floods, ice jams occasionally cause flooding in Iowa. In 2017, ice jams in January caused flooding along the Iowa River and the Mississippi River. In 2016, flooding caused by ice jams occurred along the English River, Des Moines River, Cedar River, the West Fork Cedar River, and several times and in several places along the Iowa River (near Marengo, Marshalltown and twice at Columbus Junction). In 2015, ice jams caused rivers to rise along the Mississippi River and Iowa River (particularly at Marengo). In 2014, ice jams caused flooding along the Iowa River, the Skunk River, and the Wapsipinicon River. That same year, in Cedar Rapids an ice jam caused the river to jump five feet, reportedly closing a road, and another ice jam on Beaver Creek also flooded a road. March of 2013 saw a good deal of flooding due to ice jams, occurring along the Cedar, Wapsipinicon, Big Sioux and Maquoketa Rivers. That month an ice jam also caused damage to pilings of a bridge crossing the North Fork Maquoketa River.[60]

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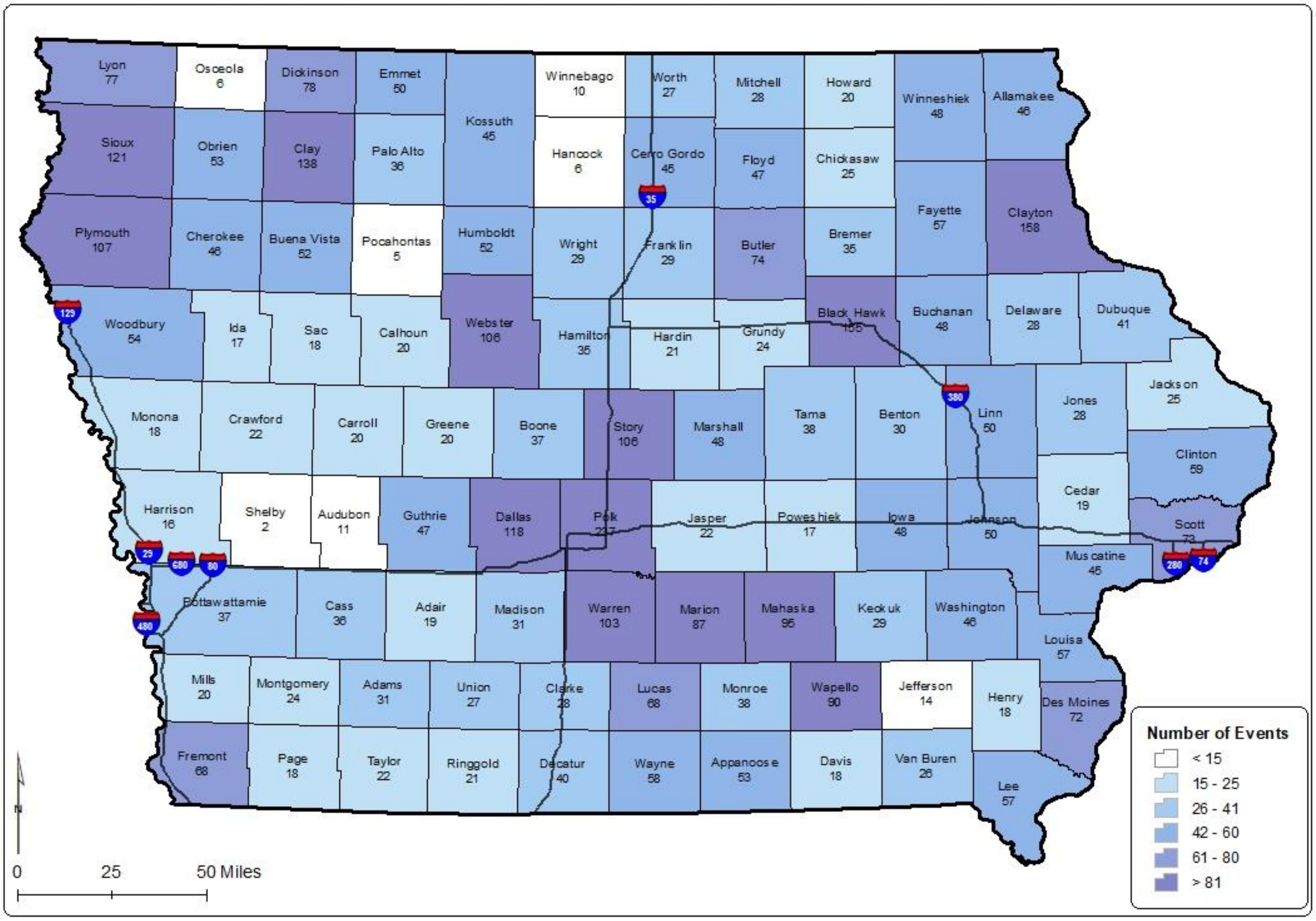
[55] https://www.desmoinesregister.com/story/news/2019/09/17/iowa-flooding-2019-missouri-river-levee-breaches-mills-fremont-county-pacific-junction-hamburg/2355669001/
[56] https://www.iowapublicradio.org/ipr-news/2019-06-25/as-water-recedes-river-cities-tally-flood-damage
[57] https://www.weather.gov/dvn/summary_SpringFlooding_2019
[58] https://www.wqad.com/article/news/local/davenport-flood-anniversary-three-years-later/526-6fc66777-fb74-4f5d-887d-2686db57c1b3
[59] https://www.iowapublicradio.org/ipr-news/2023-04-11/davenport-learning-lessons-from-2019-prepares-for-a-flooding-mississippi-river
[60] Source: US Army Corps of Engineers Ice Jam Database at http://icejams.crrel.usace.army.mil/

Flood Events 2007-2022. Flash and Riverine Flooding reported in NCEI's Storm Events Database from any cause, including snow melt, ice jams and dam/levee failures.

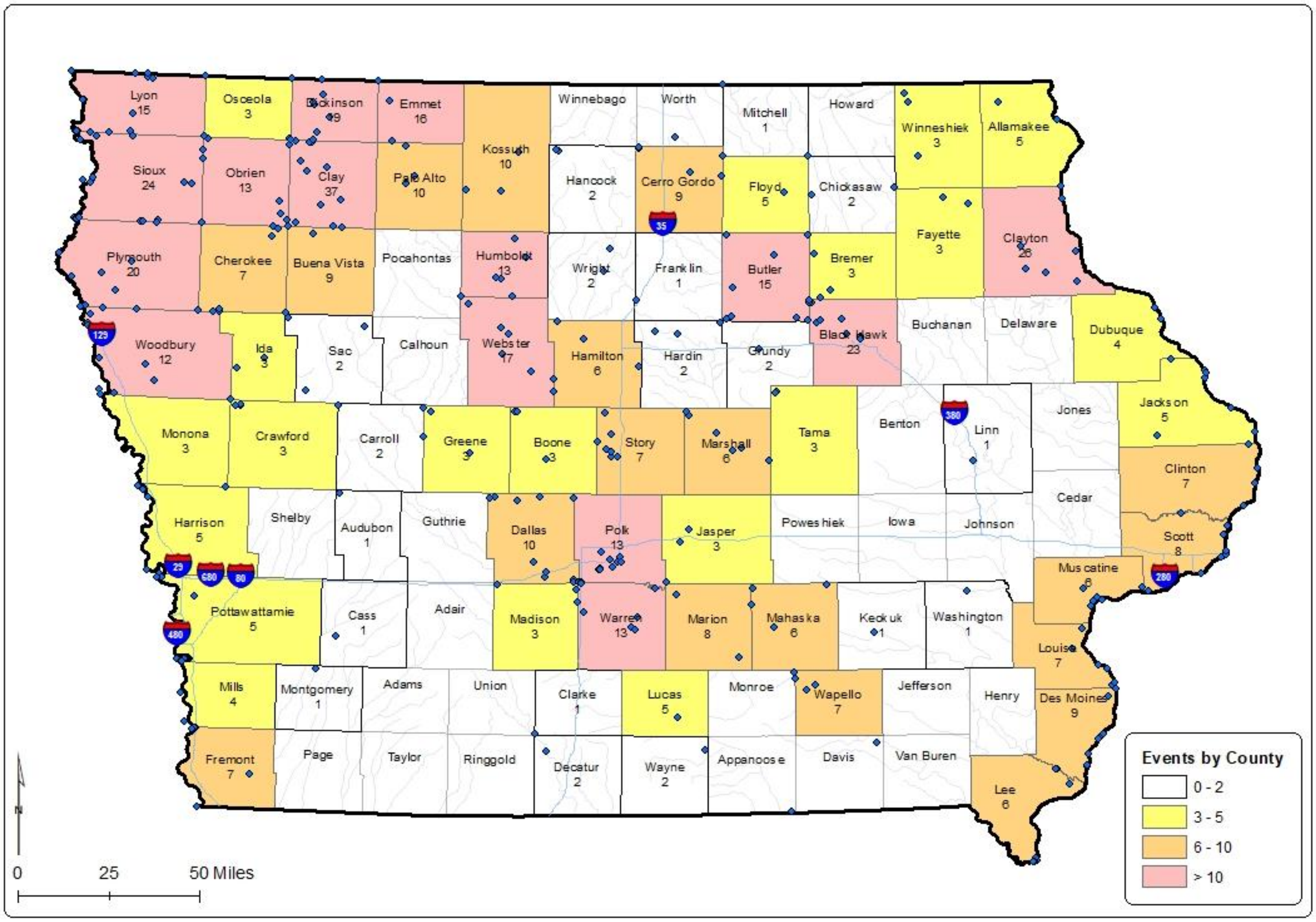


The above map shows the number of flood events in each county in Iowa for the years 2007 through 2022. The map includes events from any type of flood, whether flash or riverine, and from any cause, whether from storms, snow melt, ice jams, or even dam or levee failures. According to the NCEI data, flooding caused over 131 injuries and 8 deaths in that period.

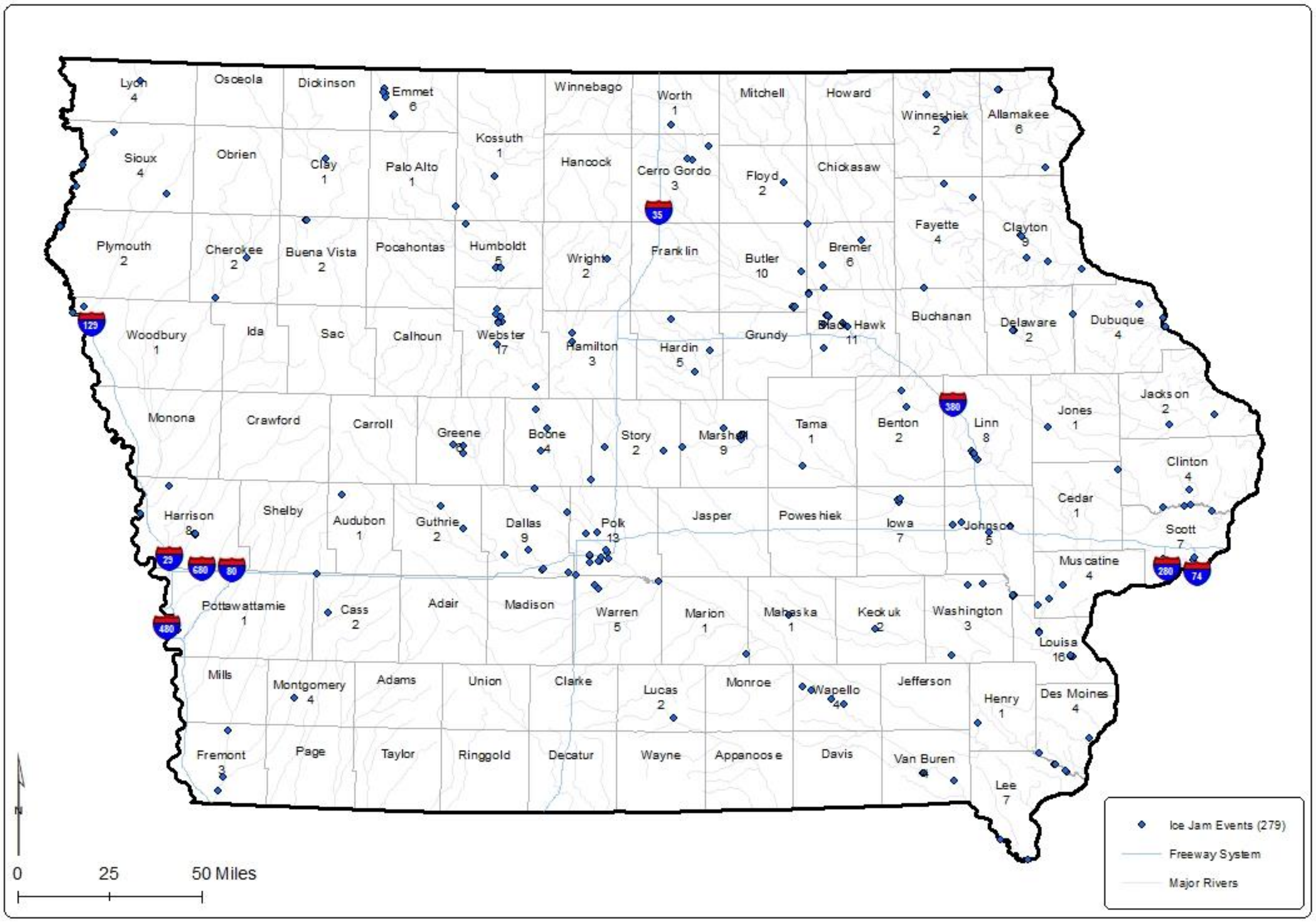
A map below shows the number of flood events due to ice jams, and another map following shows flood events that were cause by snow melt/heavy rain. (Note that flood events from dam/levee failure is addressed in more detail in a subsequent profile section, which includes a similar map for flood events due to dam/levee failure.) The floods of 2008 and 2019, as well as the devastating flooding that occurred in 1993, emphasize the importance of mitigation against river flooding in the state of Iowa. The 2008 floods resulted in 86 of the state's 99 counties being included in governor's proclamations of disaster emergency. The flooding of 2019 resulted in Presidential Disaster Declaration for 80 counties in Iowa.

Flood Events 2007-2022 Reported to be Caused by Snow Melt/Heavy Rain.

Source: NCEI's Storm Events Database



Flood Events Due to Ice Jams, 2007-2022. Source: NCEI Storm Events Database.



C. Location, Probability, and Intensity

While ice jams could form anywhere along rivers and streams, some areas are known to have a higher probability for the development of ice jams and the subsequent flooding that comes from them. Such areas of higher probability include:

- Areas where the river slope naturally decreases;
- Culverts that can freeze solid;
- The headwaters of a reservoir;
- Areas of channel constriction such as bridges;
- Bends in the channel; and
- Shallow areas where channels can freeze solid.

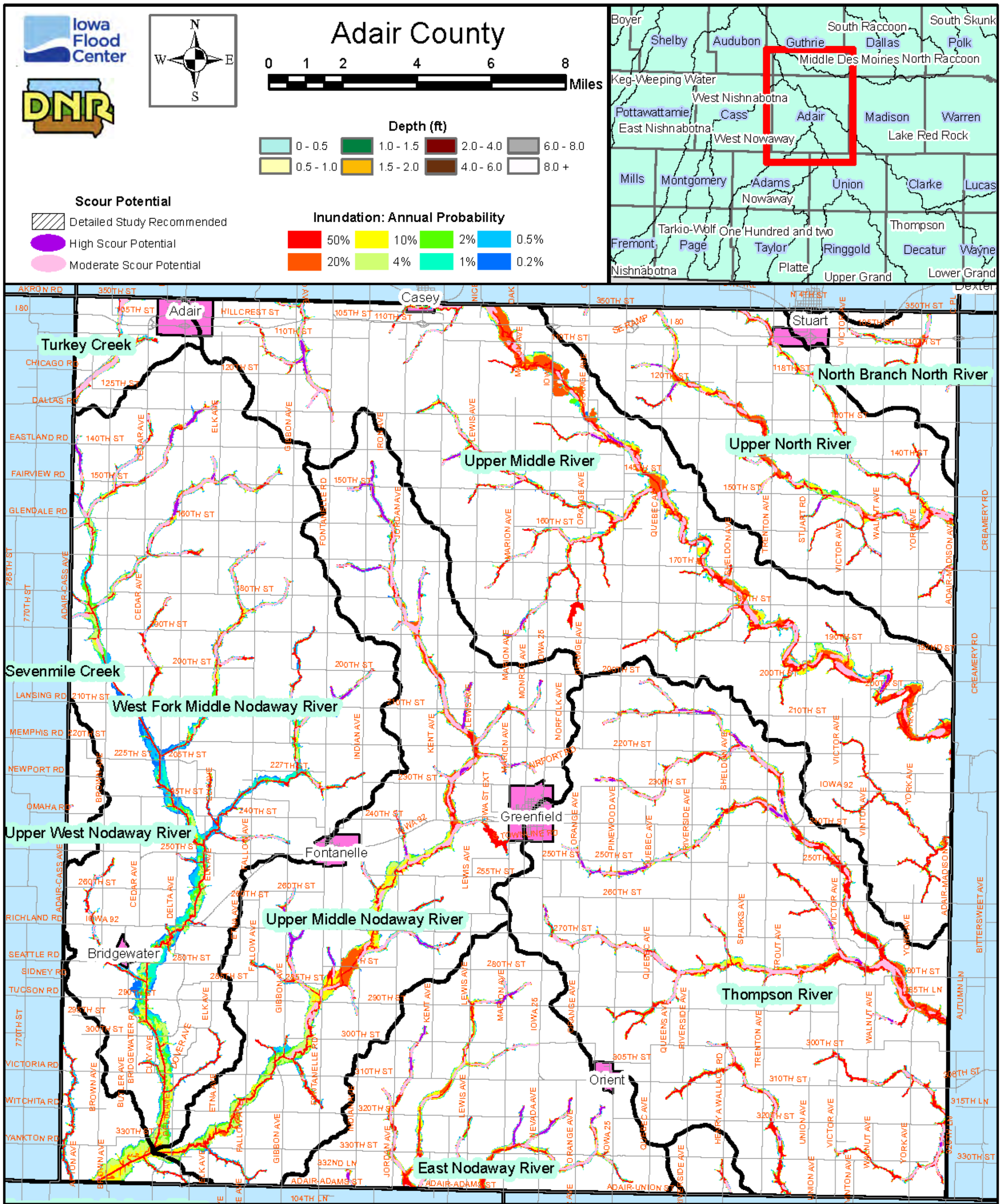
While such areas are not mapped throughout the state, mapping has become available in the last five years that shows where the areas where rivers and streams are more likely to inundate at various probabilities, as based on hydrologic and hydraulic models. The Iowa Statewide Floodplain Mapping Project ("Project") has been very instrumental in mapping such river flood areas and probabilities. Funded by the U.S. Department of Housing and Urban Development (HUD) in response to the devastating 2008 flood, the Project began in 2010 to create and update floodplain maps throughout the state. The Iowa Flood Center (IFC), the Iowa DNR and USACE, working with FEMA and the Iowa Natural Heritage

Foundation, created floodplain maps for Iowa's counties. The maps show probability, intensity, and depth of flooding for every stream draining more than one square mile.

After several years of work, the following probability and intensity flood information is now available:

- Areas likely to experience floodplain scour during major flood events
- High-resolution maps of flood depths associated with the 50, 20, 10, 4, 2, 1, 0.5, and 0.2 percent annual probabilities
- Floodplain areas associated with varying degrees of risk

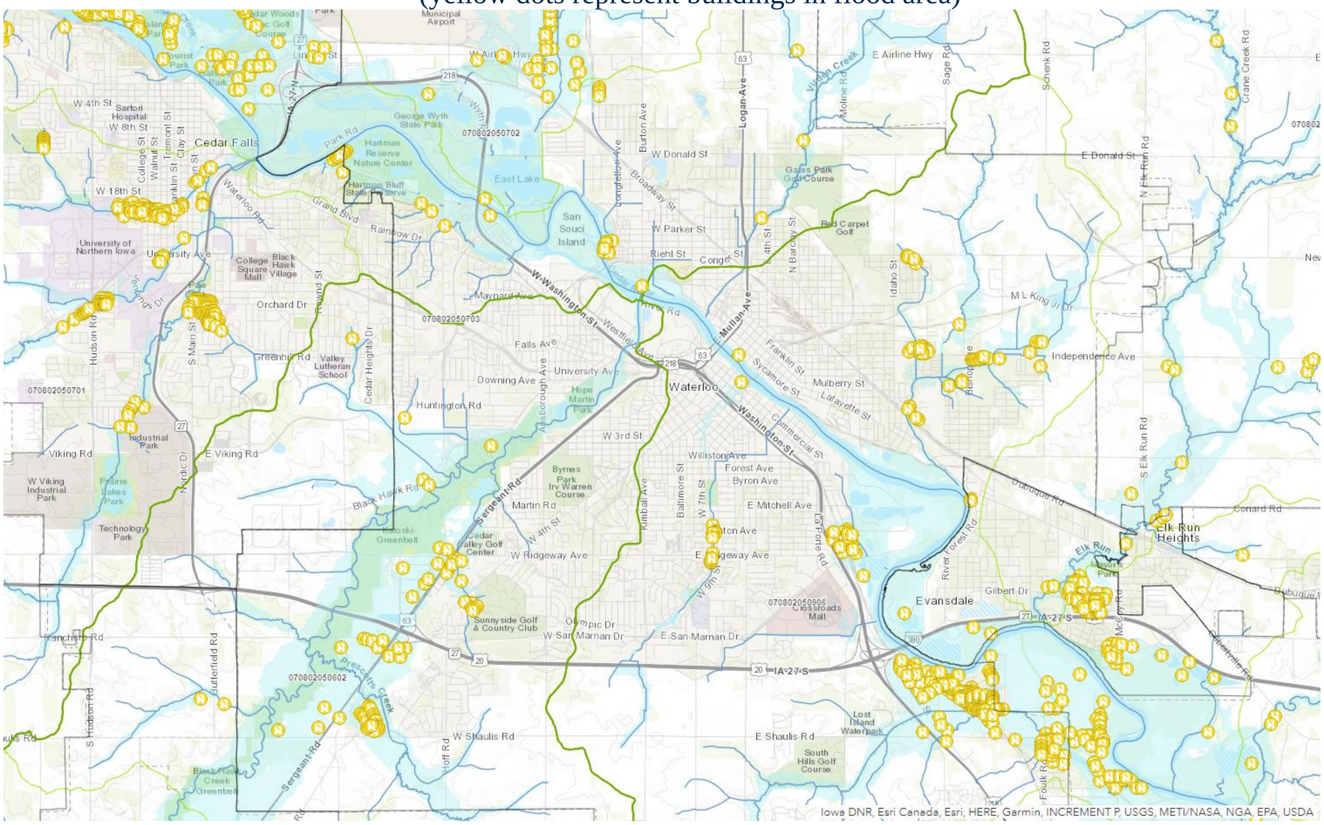
The flood risk map data for all counties in Iowa is available through an interactive online viewer at http://ifis.iowafloodcenter.org/ifis/newmaps/risk/map, and pdf maps, as shown in the example below, are available to download for most counties at http://www.iihr.uiowa.edu/iowafloodmaps/flood-risk-management-maps/.



-Scour predictions made for land cover conditions as shown in the 2009 High Resolution Land Cover database and soil conditions as shown in the 2013 USDA NRCS gSSURGO database
-Scour predictions were not made behind levees that appear to protect against the 1% annual flood
-Levees shown may or may not be accredited by FEMA

With this newly available flood risk data, along with data from county assessors, Iowa HSEMD has been able to produce analyses and maps like those shown in the next two maps of the Waterloo area in Black Hawk County. The first shows a map of the area that would be inundated by a flood event with a probability of 0.2% in any given year (i.e. a one in 50 chance, or an average recurrence interval rate of once every 50 years). The map also illustrates results of GIS analyses that show buildings in the inundation area of that 50-year recurrence interval (RI) flood.

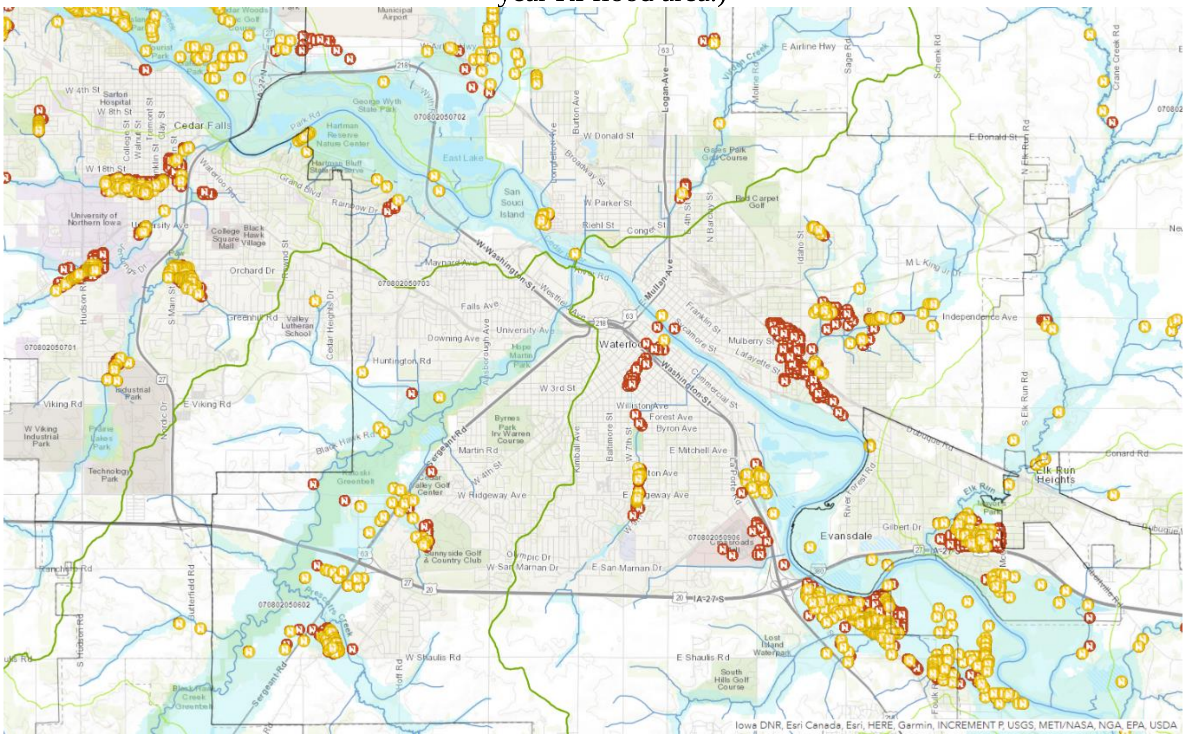
Inundation Area of 50-Year RI Flood for Waterloo-Cedar Falls
(yellow dots represent buildings in flood area)



This next map shows the same area of Black Hawk county, but instead shows the inundation area of the 500-year RI, and the buildings that would be flooded therein.

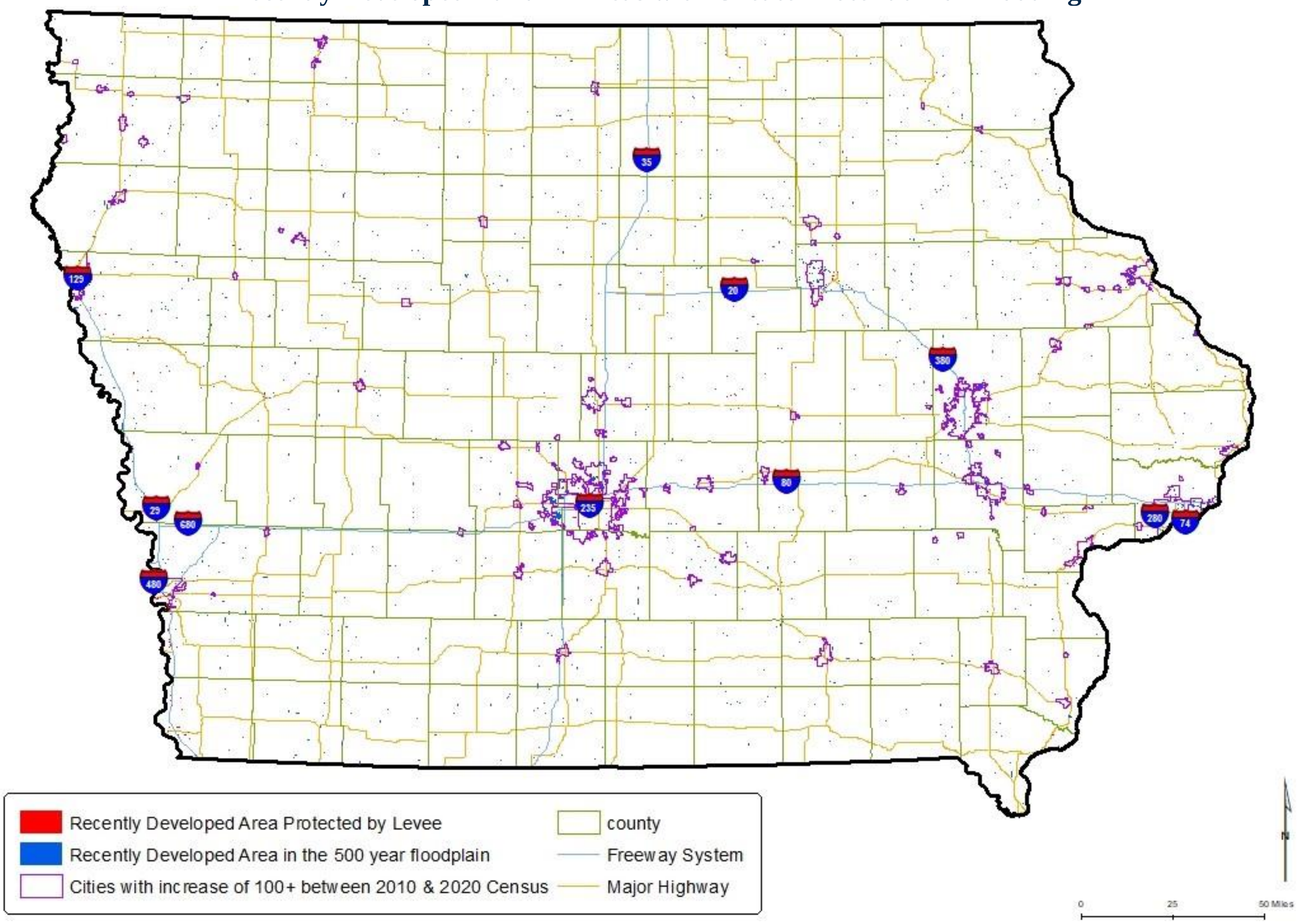
Inundation Area of 500-Year RI Flood for Waterloo-Cedar Falls

(Yellow dots represent buildings in 50-year RI flood. Red dots represent additional buildings in 500-year RI flood area.)



Analyses and mapping have been done for all areas of the state for other recurrence intervals as well to show where existing buildings would be flooded. GIS analyses also has been used to show where very recent development (developed since 2010) would be inundated. The map below shows where such recently developed land in Iowa is subject to inundation from a 500-year RI flood.

Recently Developed Land in Areas with Greater Potential for Flooding



While there is a good deal of data to illustrate the probability of river flooding for many parts of the state, such data for probability of flash flooding is not available. Records from NCEI's Storm Events Database, however, do show the number of flash flood events each county has had in the past. From these records, it is evident that Polk County has had the most flash flood events on an average annual basis. Story County would be second over the same time period (meaning either 1996 to 2022, or 2007 to 2022). Over the period 2007 to 2022, the counties in the adjoining list have had the most flash flood events, which gives some indication of where probability of flash flood events is highest.

County	Flash Flood Events 2007-2022
Polk	101
Story	58
Webster	46
Dallas	43
Linn	42
Johnson	40
Buchanan	38
Appanoose	36
Guthrie	36
Black Hawk	34
Scott	34
Wapello	33
Warren	33
Dubuque	33

It is worth noting that most of these counties are increasing in the average number of flash flood events they experience each year; only Buchanan, Dubuque, and Scott have not (comparing the rate from 1996 to 2007 vs. 2007 to 2022, derived from NCEI's Storm Events Database records).

Such data, in and of itself, is not extensive enough to conclude that flash flooding is necessarily increasing. However, other data also indicates that flood events may be trending upward. The report *Climate Change Impacts on Iowa 2010*[61] *(*"Report") notes that there is a trend toward more frequent intense rainfall events. If this trend continues, flash flooding events and their associated impacts will likely occur more often in Iowa. As for riverine flooding, very heavy precipitation does not always result in flooding, but it can when the very heavy precipitation occurs frequently without enough time for the watershed to drain properly.

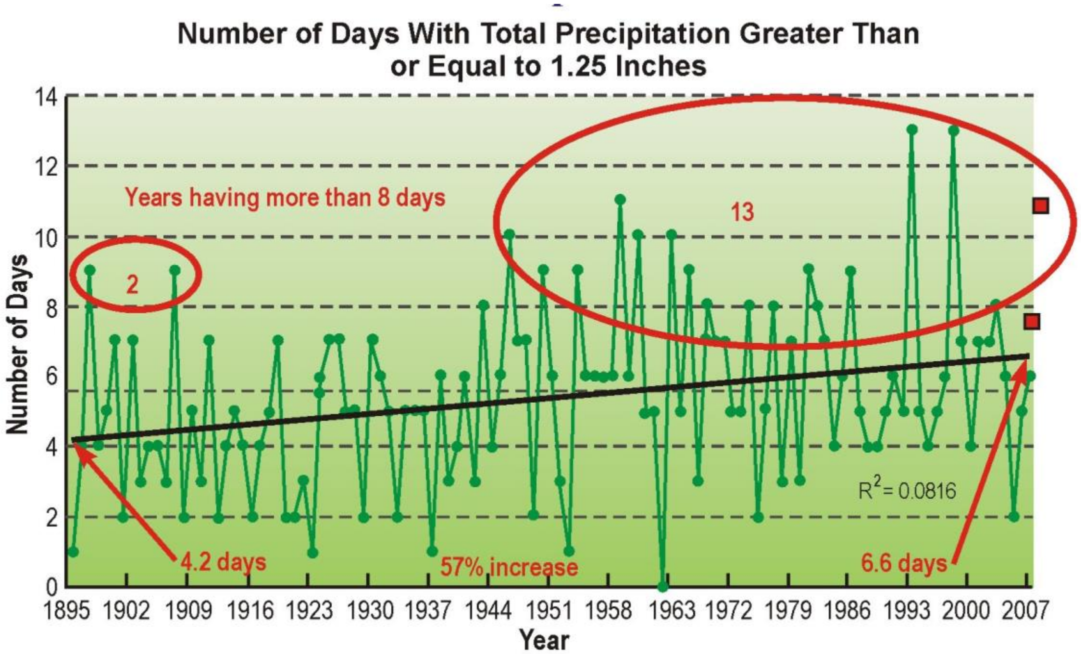
The impact of these climate changes in Iowa may be impacting eastern Iowa more than the rest of the state. The following paragraph and figures from pages 8-10 of the Report illustrates how precipitation is increasing more in eastern Iowa than it is in western Iowa (though precipitation seems to be increasing in most parts of the state):

> Precipitation in Iowa has gradually increased over the last 100 years, although year-to-year variability is high. Eastern Iowa has a higher upward trend than the statewide average. . . . Trends toward more precipitation . . . as well as higher increases in eastern Iowa, are projected to continue (IPCC 2007). . . . Records for Iowa also show a higher tendency for more intense rain events, as shown in [the figure below] for Cedar Rapids, which has experienced a five-fold increase in number of years having eight or more days with daily total precipitation exceeding 1.25 inches (3.0 cm). Des Moines also has experienced an increase in days with total precipitation exceeding 1.25 inches.

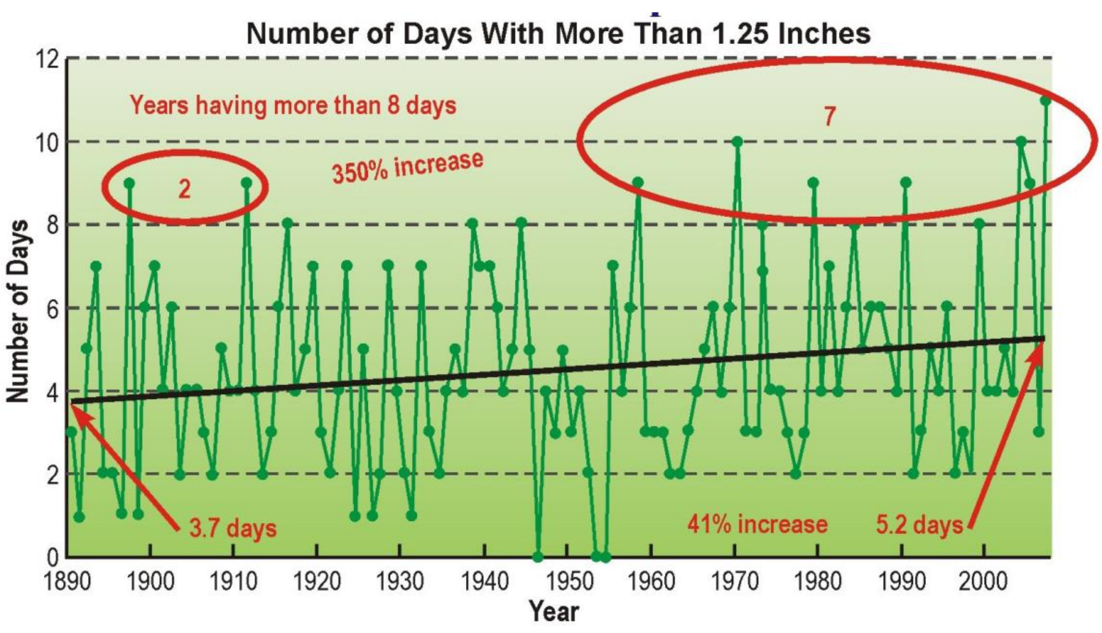
According the report, the increase in precipitation has contributed to a rise in streamflow levels and the potential for more frequent and greater flooding.

[61] J.L. Schnoor and E.S. Takle. (2011*) Climate Change Impacts in Iowa 2010: Report to the Governor and the Iowa General Assembly*. www.iowadnr.gov/iccac/. Accessed May 11, 2018.

Cedar Rapids Data:



Des Moines Data:



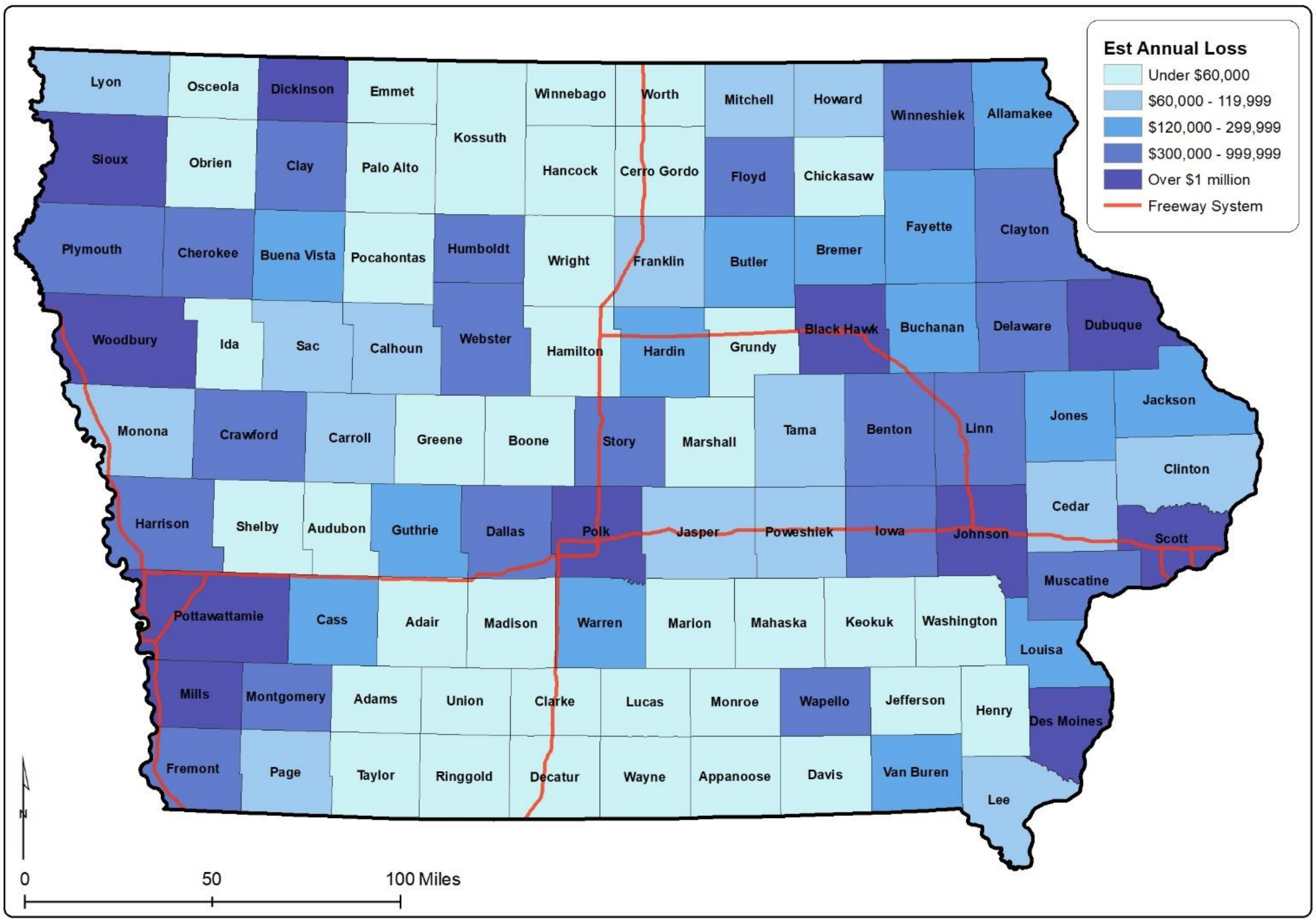
D. Summary of Vulnerability: Most Vulnerable Areas

As mentioned above, HSEMD has utilized the recent floodplain mapping and data from county assessors to perform analyses with Hazus modeling software to create flood-risk assessments that show areas of greatest vulnerability.

The Iowa Flood Center also has vulnerability and damage estimates for various flood probabilities shown on their online Iowa Flood Information System for several communities.[62] Communities with such information available include Cedar Falls, Cedar Rapids, Des Moines, Fort Dodge, Independence, Iowa City, Kalona, Monticello, Ottumwa, Rock Rapids, Rock Valley, Waverly and Waterloo.

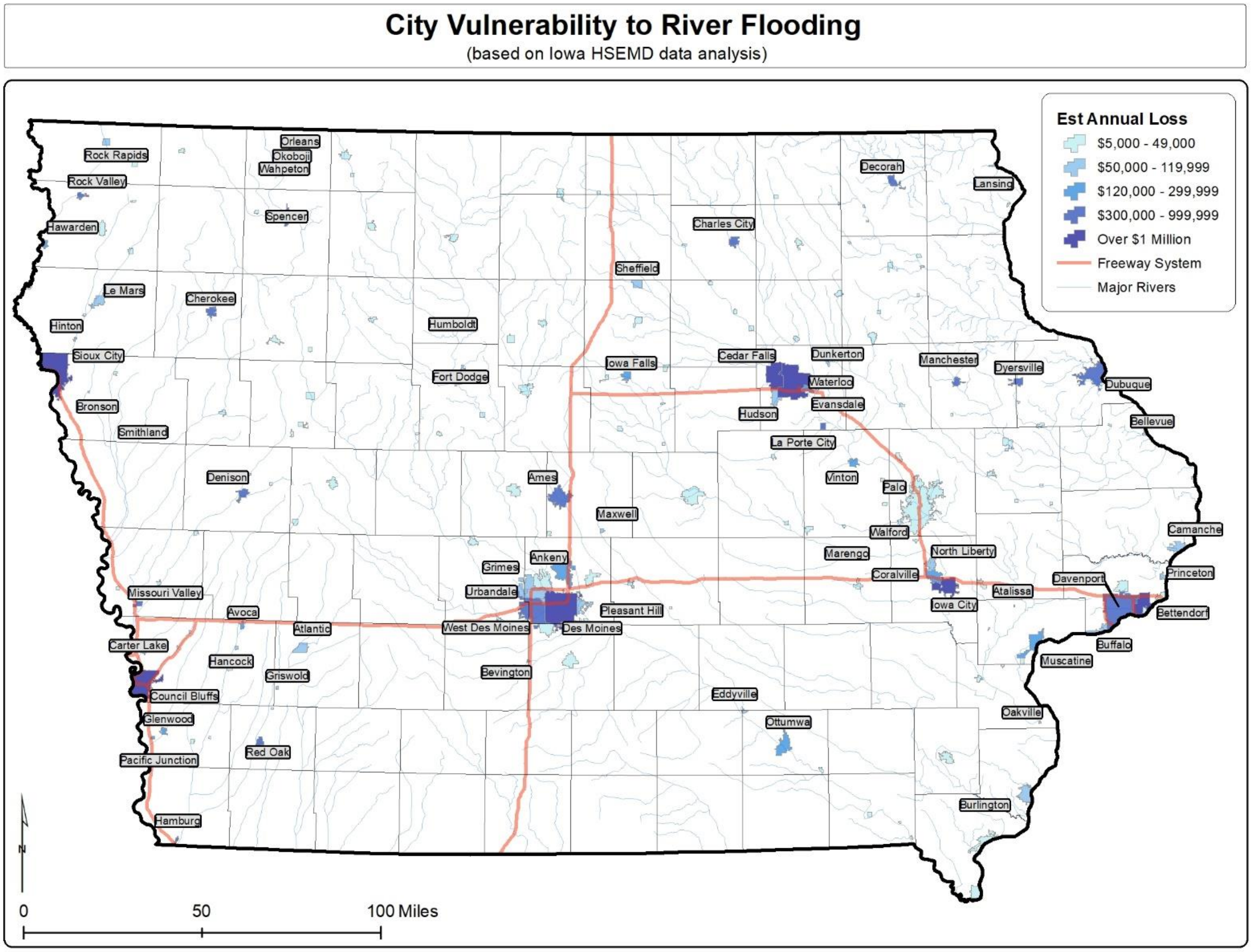
The most vulnerable areas to flood damage, based on the statewide analyses completed by HSEMD, is summarized on the following two maps. This first map shows the counties with the highest estimated average annualized flood loss.

County Vulnerability to River Flooding
(based on Iowa HSEMD data analysis)



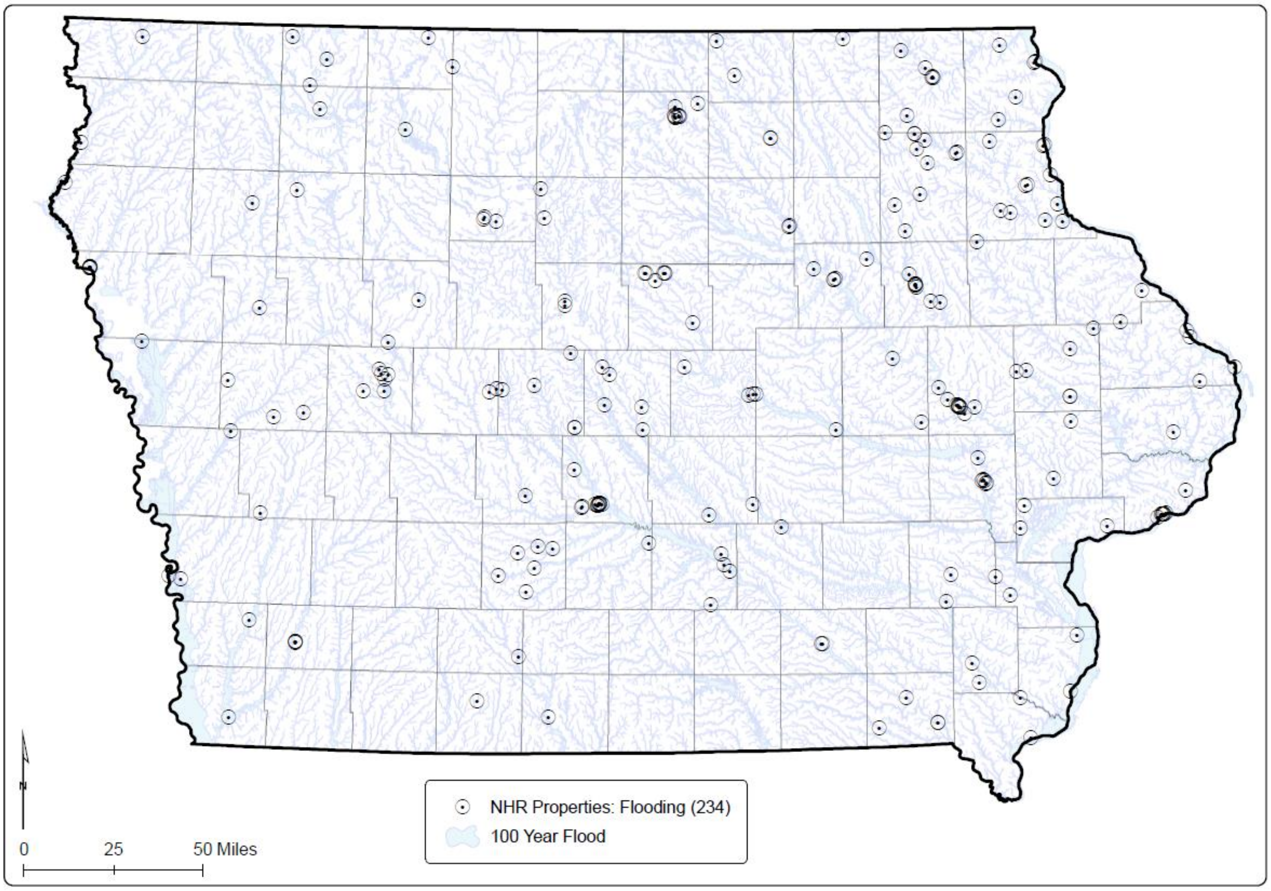
This second map shows the cities with the highest estimated average annualized flood loss:

62 http://ifis.iowafloodcenter.org/ifis/en/app/. Accessed May 11, 2018.



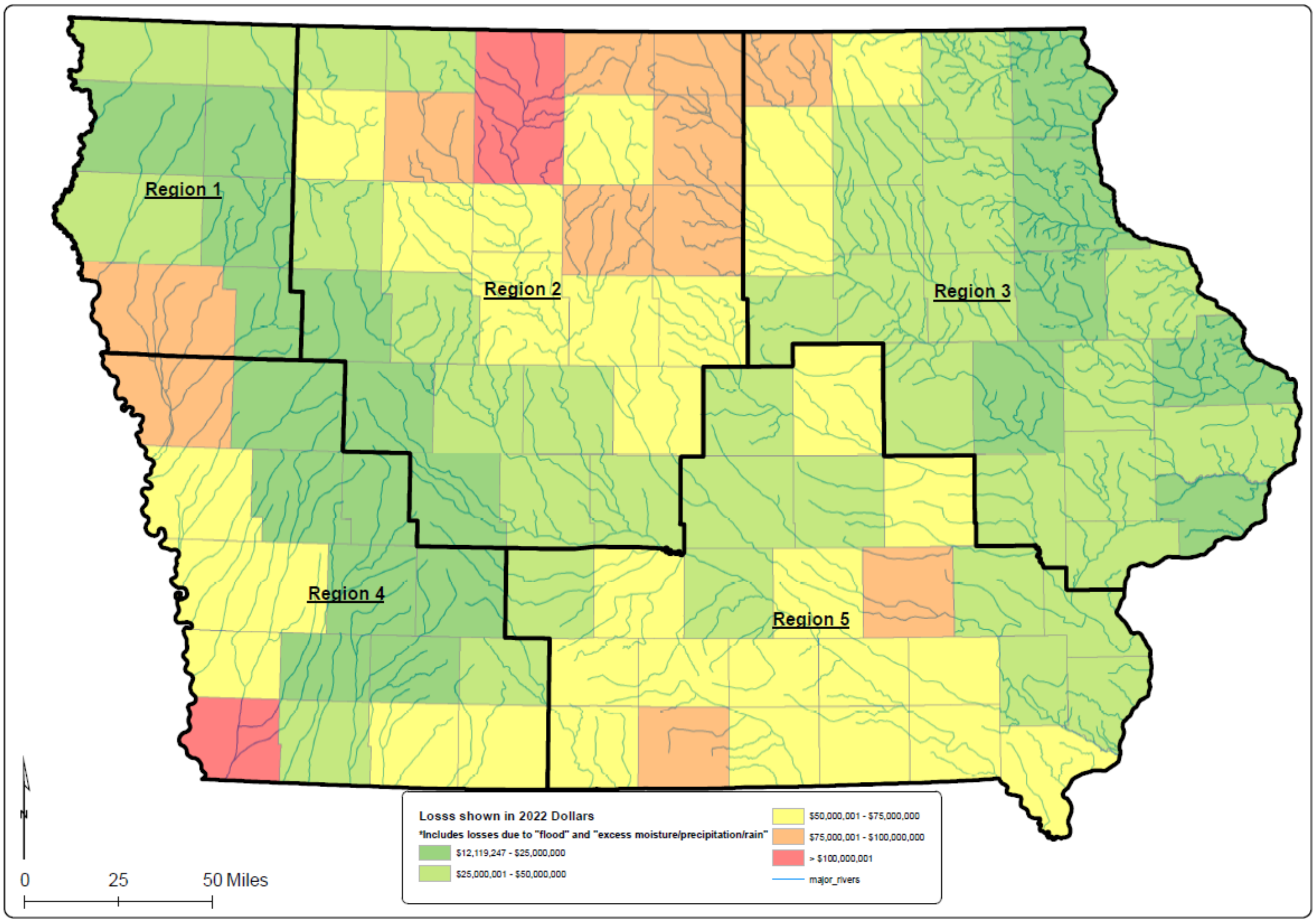
The maps above show vulnerability based on damage to buildings. Counties and cities can also be vulnerable to riverine flood impacts in other ways, like damage to historic buildings or crops. Also, flooding causes impacts to transportation routes which has cascading effects to community lifelines and facets of life. The following three maps illustrate these other flood vulnerabilities. The first map shows historic buildings subject to a 100-year RI flood. Valuation, in dollars, can be estimated for such buildings, and indeed is figured into the flood loss estimates and analyses illustrated in the maps above. However, historic buildings have other value that cannot be expressed monetarily. Thus, this map shows such non-monetary assets that are vulnerable to flooding.

Historic Buildings in Areas Subject to Flooding



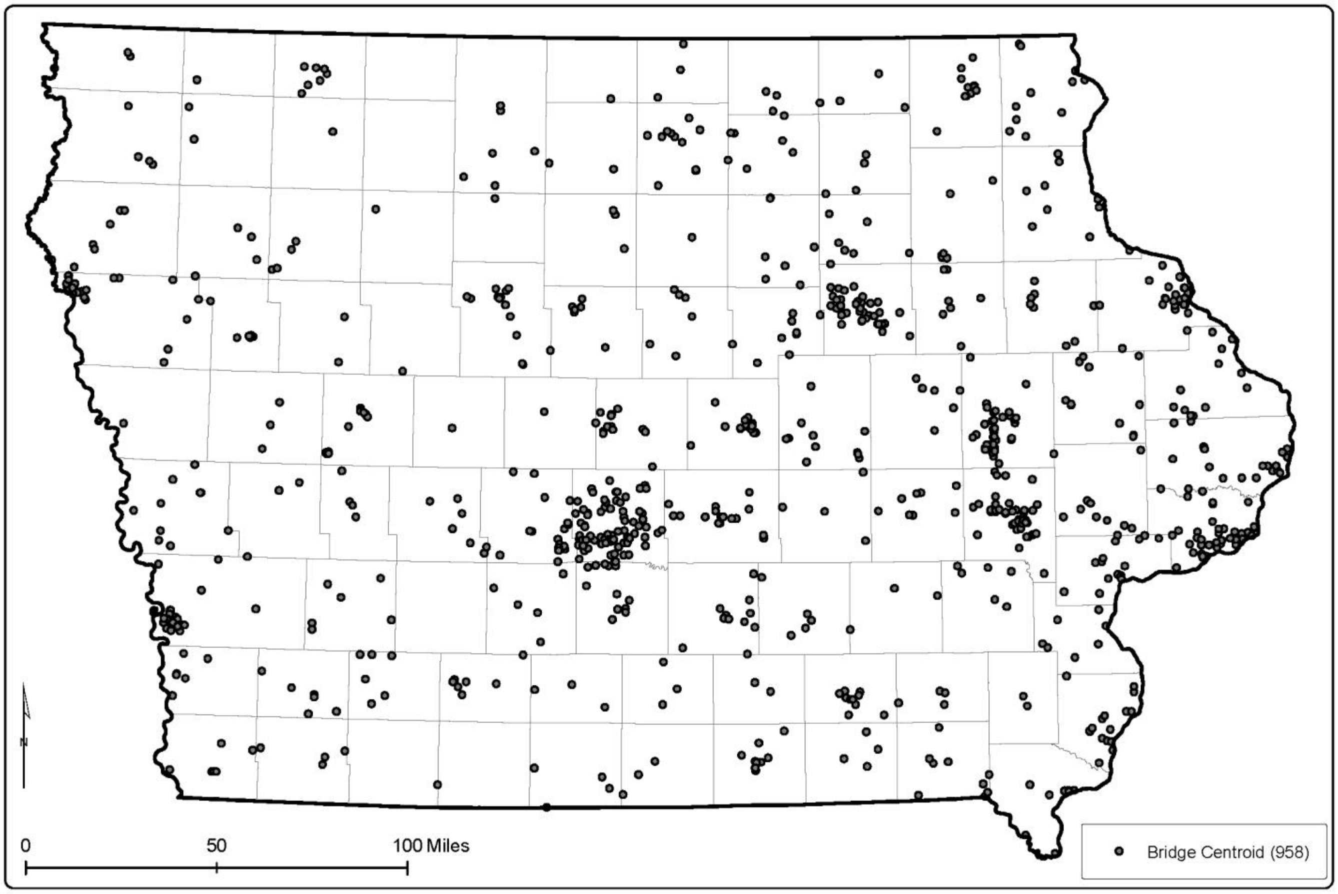
This next map shows, based on past flood losses documented in insurance claims, the counties that have been most vulnerable to crop loss.

Inflation-Adjusted Crop Insurance Claims due to Flooding (1989-2022)



This next map shows the locations in the state most vulnerable to disruptions in highway traffic due to flooding (based on data from the Iowa DOT with GIS analysis by Iowa HSEMD).

Bridge Approaches that Experience Occasional* Overtopping that Causes 1000+ Vehicle Detour Miles (Avg./Day)**

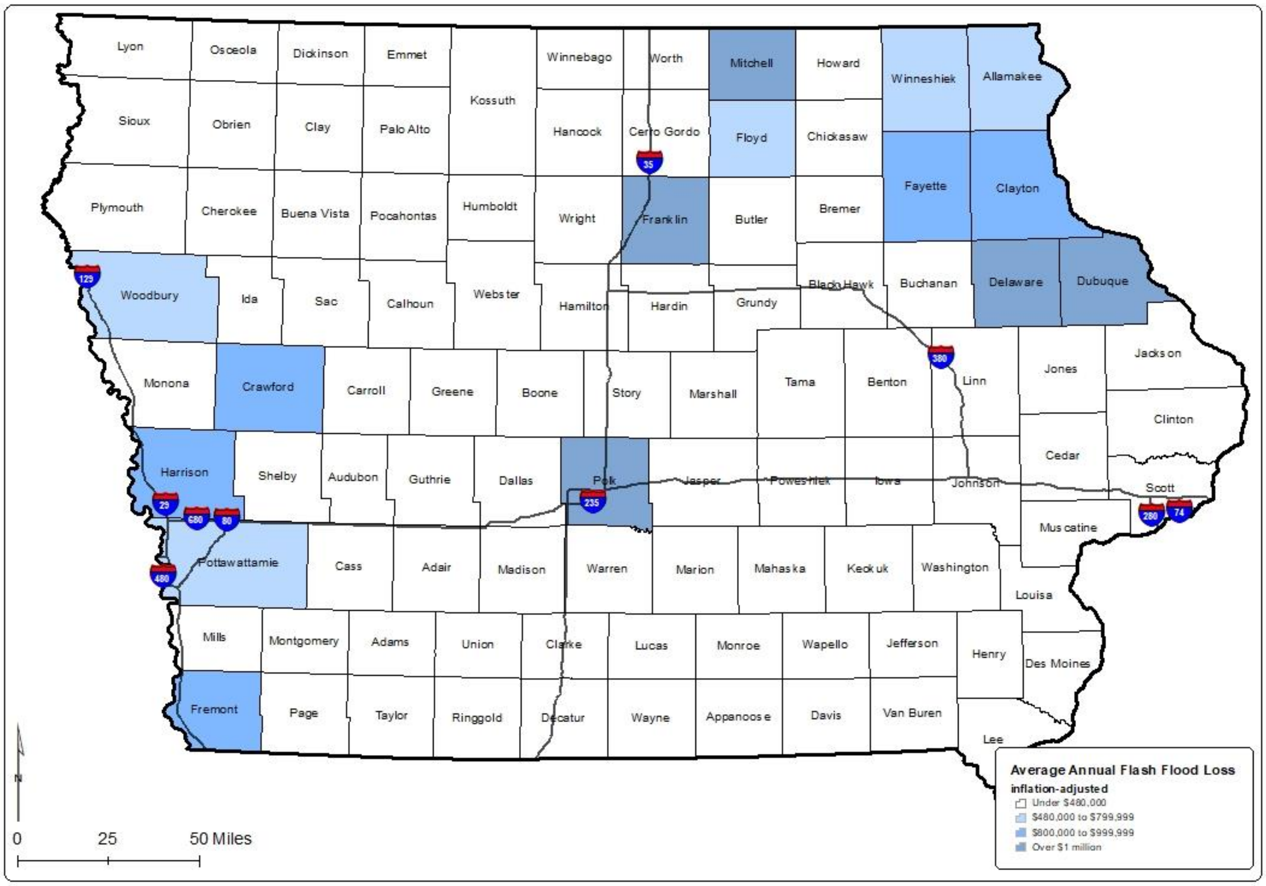


* 'Occasional' reported to be every 3-10 years (but engineering analysis may not show this). ** Based on AADT multiplied by detour bypass distance (for one day of detour).

While there is good information to determine <u>riverine</u> flood vulnerability across the state, at present <u>flash</u> flood vulnerability cannot be determined for the entire state because there is not a reliable source of scientific data (i.e. flood models or studies done by engineers or other certified professionals). In lieu of that, the map below shows historical data to illustrate the counties where most flash flood damage has occurred in the past.

Counties with Highest Flash Flood Loss

Based on 1996-2022 NCEI Storm Events



The above maps illustrate analysis of flood vulnerability statewide. In addition to analysis and research of flood vulnerability from statewide resources, county hazard mitigation plans were reviewed and explored to note the kinds of flood vulnerability reported. While the data from these sources was somewhat spotty, and therefore precluded a comparison of all counties, there are some items of interest from the local mitigation plans that are worth reporting. Several local plans reported on the number of buildings, including critical facilities, that are found within floodplains. Several cities and counties have been successful in removing many of these facilities from flood areas, but issues still remain. For instance, the Clayton County plan reports that while "numerous homes and businesses have been removed from the floodplain over the last decade, some still remain." Cities in Dubuque, Johnson, Scott and other counties have had similar experience. In Johnson County, the local hazard mitigation plan reported that they no longer had any repetitive loss properties, whereas there had been 11 such properties five years prior.

Many local plans also reported on how vulnerability has been increasing due to new development in areas with some probability of flooding. But, many local jurisdictions are addressing what may become a worse problem by enacting policies and standards. For instance, in Linn County new code language was "pending to strengthen the Floodplain Ordinance to reduce development in the floodplain in unincorporated Linn County." Also in Linn County, the City of Robins now requires detention basins in new development.

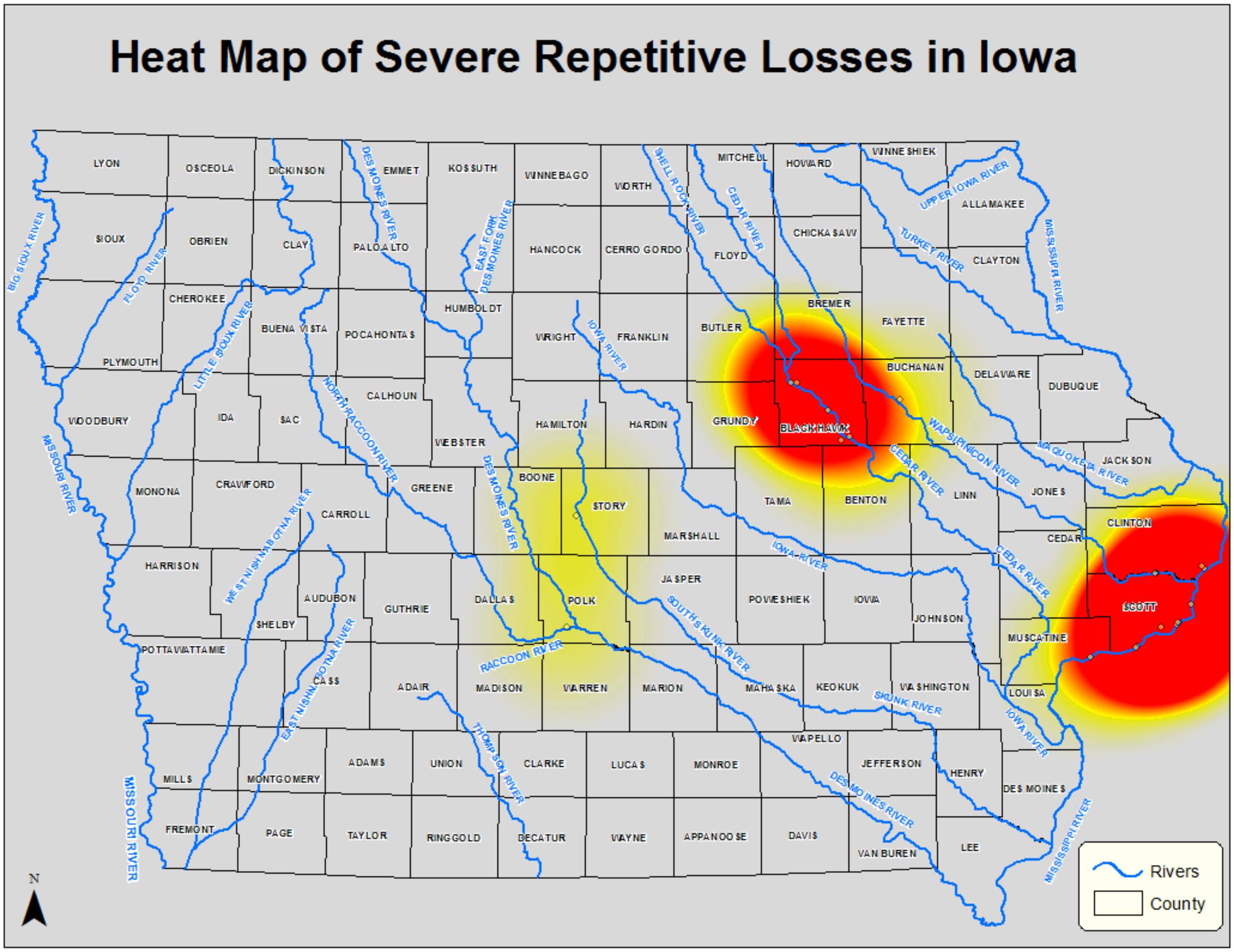
Dealing with flooding has certainly been a constant struggle at the local level. Many recent mitigation projects have reduced flood vulnerability, but new threats continually emerge that must be addressed. For instance, several mitigation projects have been completed in Dubuque County that reduce vulnerability in areas with past damages, but then established businesses are seeing flooding in the Couler Valley watershed that have not flooded before. New development is occurring in this area, and the mitigation plan recognized the vulnerability there "until the Flood Plain Management Ordinance is amended to restrict filling in and development of the flood plain in this area". Local mitigation planning helps communities recognize their vulnerabilities and began the steps to mitigate their flooding.

E. Repetitive Loss Properties and Flood Insurance

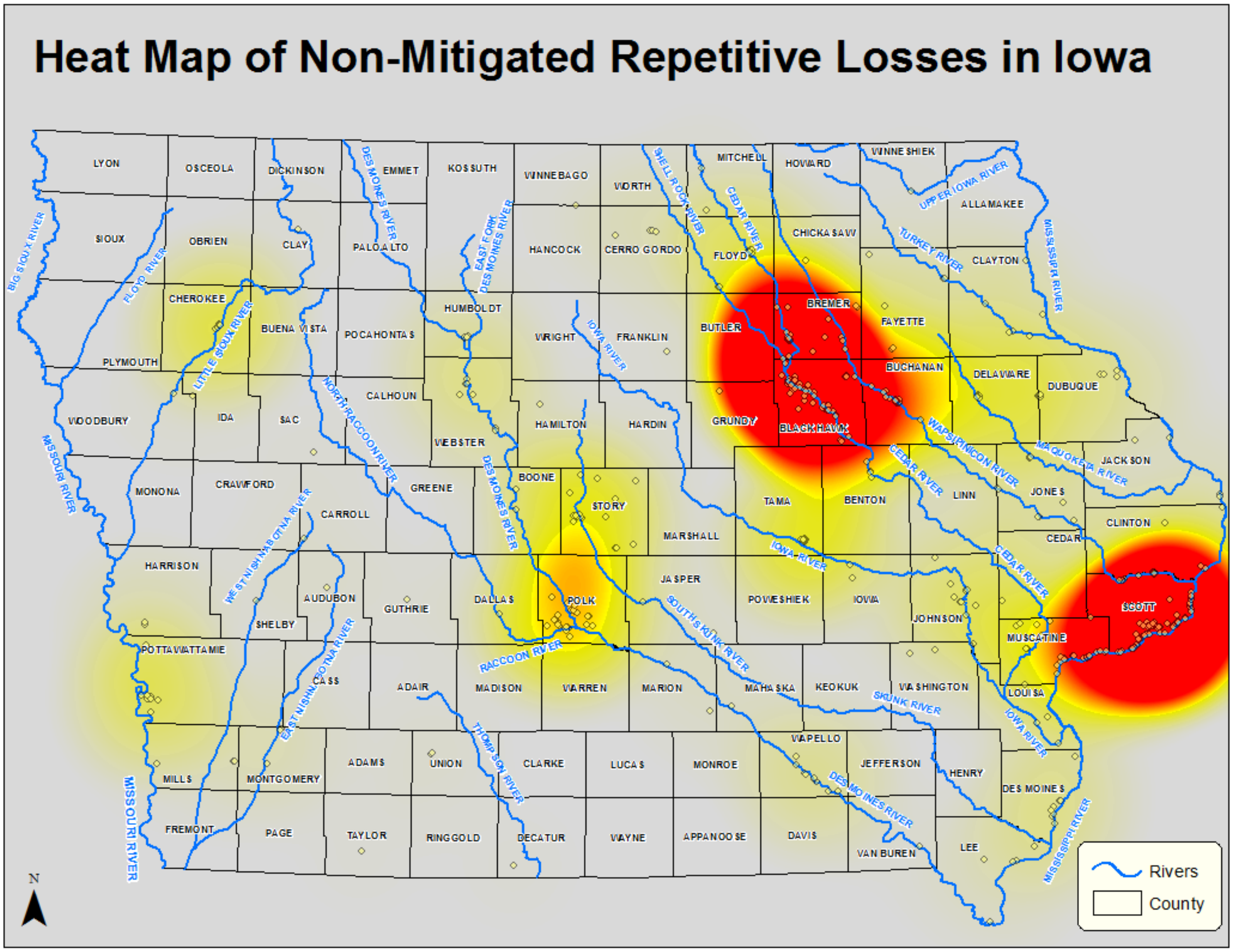
The National Flood Insurance Program (NFIP) repetitive loss properties (RL) and severe repetitive loss data identifies properties that have experienced multiple flood losses. Less than two dozen properties in Iowa may be classified as a severe repetitive loss property (SRL). An SRL is defined as a single family property covered by NFIP insurance that since 1978 has incurred flood-related damage for which claims payments have been made for:

- Four or more separate claims of more than $5,000 each (including building and contents payments); or
- Two or more separate claims (building payments only) where the total of the payments exceeds the current market value of the property

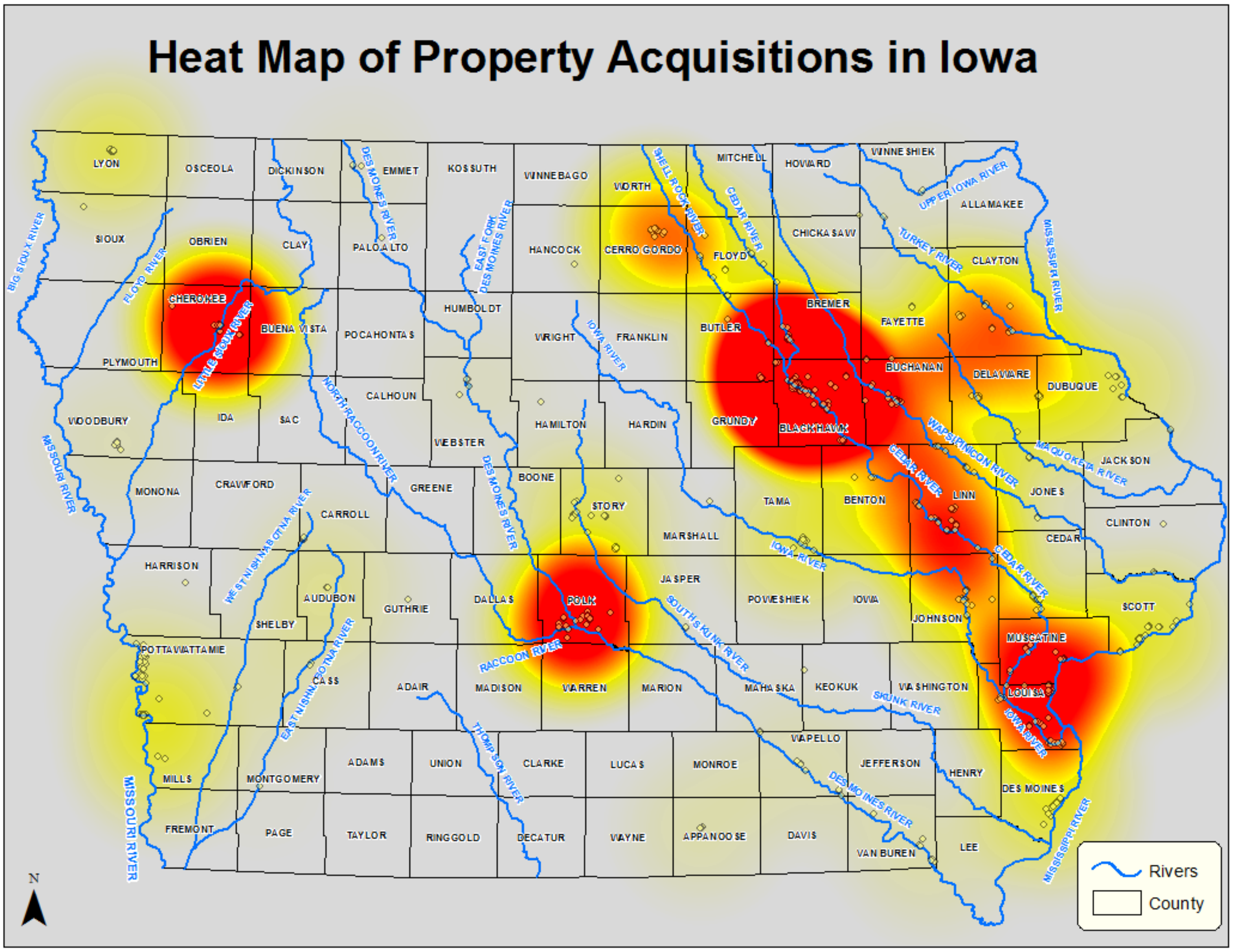
The map below summarizes and illustrates the locations of SRL properties, as of 2022.



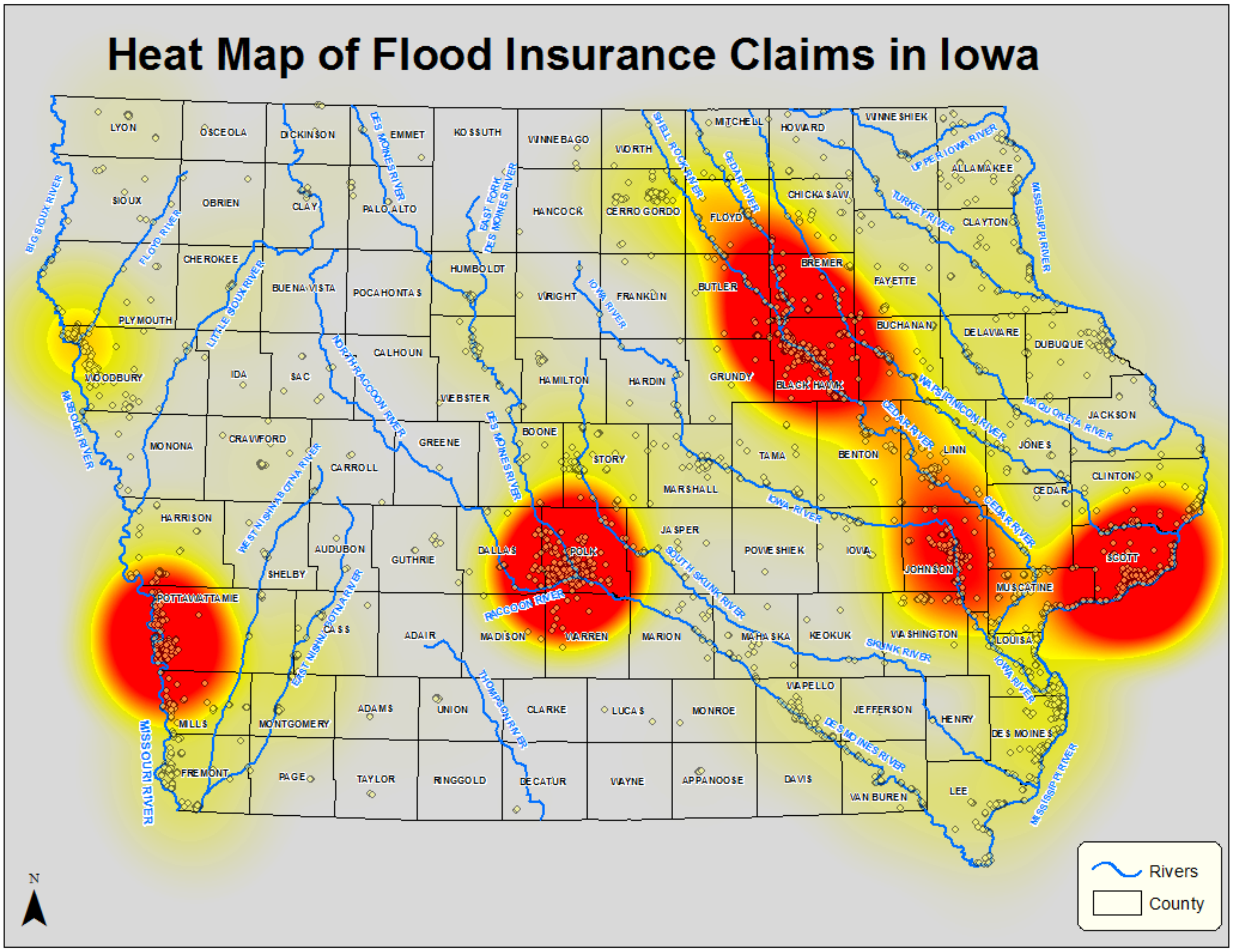
This next map shows the location of RL properties in Iowa, as of 2022.



In the past, there were even more repetitive loss properties, but many have been acquired with Hazard Mitigation Assistance (HMA) or other funds in order to mitigate further loss. The map below gives an indication of how many properties were acquired and their location. Of those acquired, a total of 128 were repetitive loss properties acquired with HMA funds since 2009.

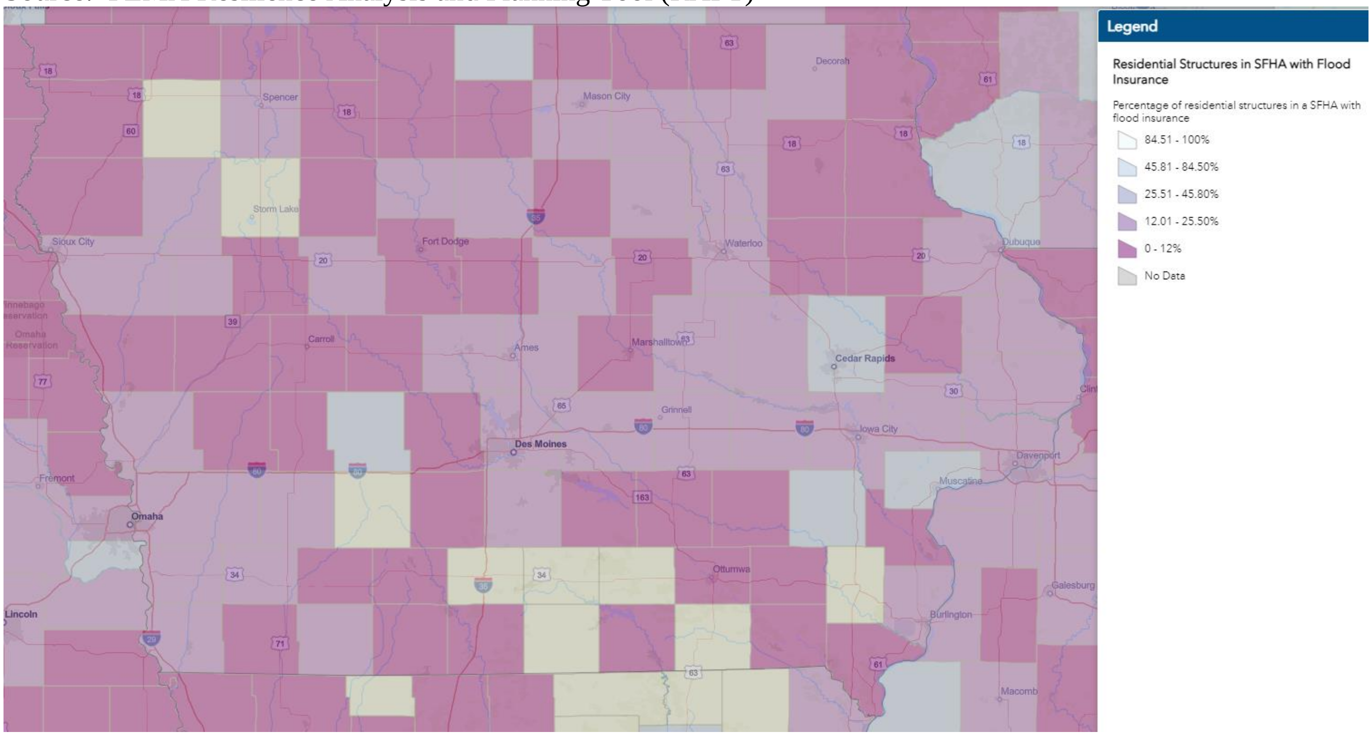


The locations of claims against NFIP policies shows a picture similar to the areas shown above. This next map illustrates where those claims have been.



The number of NFIP policies in Iowa, as of June 2023, is 8,335. From HSEMD's flood loss estimate analysis (referenced above), there are about 30,370 structures in the area subject to a 1% annual chance of flooding (i.e. the 100-year flood zone). So, that means that about 27% of the structures in the 100-flood zone have flood insurance. According to FEMA's Resilience Analysis and Planning Tool (RAPT), the map below shows the counties with the highest proportion of flood-prone homes that lack flood insurance.

Counties with Highest Proportion of Flood-prone Homes Lacking Flood Insurance
Source: FEMA Resilience Analysis and Planning Tool (RAPT)[63]



The number of NFIP policies in Iowa has been decreasing. In 2018 there were 12,340 policies, in 2022 there were a total of 9,218 policies, and the latest count is 8,335. The decrease in policies are caused by a number of factors, including:

- Premium increases called for under the 2014 HFIAA reform
- State-wide mapping effort reducing the extent of SFHAs especially approximate A zones
- Lenders being able to accept private insurance
- Risk Rating 2.0 (new methodology for calculating NFIP insurance rates)

It is interesting to note that while the number of policies has decreased, the number of NFIP participating jurisdictions has increased. In 2018 there were 672 participating communities, in 2022 a total of 691, and the latest count in 2023 there were 711.

F. Summary of Problem and Identification of Possible Actions to Mitigate Problem

Runoff from precipitation is a natural occurrence, and of course the magnitude of it ebbs and flows, which has always been the case. In other words, what we call "flooding" has been in Iowa forever. But, the magnitude of it is aggravated by increasing intensity of rainfall events and changes in land use in the watershed. When land use changes from fields or woodlands to roads and parking lots, it loses its ability to absorb rainfall. Such urban development, with significant impervious surface, has been known to increase runoff two to six times over what would occur on natural terrain. If measures are not taken to

[63] https://experience.arcgis.com/experience/618796a76ff54ebe8bbdb677096d49ed/?views=View

limit or slow runoff in developing areas, floods may become more frequent. Also, where property is developed in areas too close to flood ways, flood events may have greater impact than in the past. In certain areas, aging storm sewer systems were not designed with enough capacity to handle increased storm runoff. Then again, other storm sewers built in the past may convey water too quickly and efficiently to streams and rivers resulting in peak flows that result in flood events downstream.

For road flooding, a possible solution is to raise the road or increase the size of culverts or drainage ways under the road. Perhaps berms or levees could be built alongside the road to route floodwaters. Such flood mitigation strategies are often employed by communities, but they do little to reduce flooding of buildings downstream. In fact, such strategies can make the situation worse for downstream properties by either speeding the water along or pushing it off one protected area onto an unprotected area.

A more resilient flood mitigation option, however, could be "watershed approach" flood reduction. A watershed approach to flood reduction is one in which practices or structures are installed upstream from the flood-prone area so that floodwaters either soak into the soil (i.e. infiltration), or are slowed down or held back (detention, storage or diversion). Where it works, the benefits of watershed approach flood reduction include:

- Reducing losses from flood damage
- Greatly minimizing adverse impacts to those downstream (because the problem is not pushed downstream)
- Lowering flood elevations not only at the flood-prone area of focus, but also additional flood-prone areas further downstream
- Improving water quality and wildlife habitat
- Possibly improving soil health and sustainability (depending upon specific methods used)
- Compared to other flood mitigation methods, reducing on-going maintenance through the use of nature-based methods
- Providing greater resiliency by making the community better able to withstand heavy rainfall events while reaping additional benefits

With so many advantages over more traditional methods of flood mitigation, one may wonder why a watershed approach to flood mitigation isn't used more often, or even exclusively. One of the key reasons that watershed approach flood reduction is not used more often is that it does not work everywhere, or at least it is not cost effective everywhere. Certain factors help determine how feasible it might be. Another reason it is not used often is because the specific methods or practices to be placed upstream to achieve flow and flood reduction are not well understood by local officials, or even engineers that may help them. Different methods have different capacities for infiltrating or detaining water. Some work with flood events of the 10-year recurrence interval (RI), some for the 25-, and others for the 100-year RI. Some can work for any one of those. The standards of practice and engineering protocols are not easy to understand, and require professional assistance. Another barrier to communities using a watershed approach for flood reduction is getting that professional assistance. They need professional assistance, usually in the way of engineering, to determine how much streamflow needs to be reduced to decrease flood impacts. They need engineering to draft designs and determine costs of a project. They need assistance in completing all the requirements to get funding from grant opportunities and other financial assistance. Finally, once the watershed approach project is designed, communities need funds to pay for construction and implementation of the project. Several actions could be taken to address these barriers to utilizing a watershed approach to achieve flood mitigation, and will be listed below. But it must be remembered, as mentioned, a watershed approach does not work everywhere for mitigating floods. Other mitigation actions will be required.

Another issue to be addressed when considering the flood problems facing Iowa is the increasing precipitation trends. As noted previously, precipitation is increasing statewide, but more so in eastern Iowa. Eastern Iowa will need increased focus to address flooding that will potentially worsen over time.

Many different actions, including nature-based watershed approach as well as more traditional methods, may be taken to address Iowa's flood problems. The mitigation actions considered in the state's mitigation planning process include:

- Provide training, funding, or outreach encouraging adoption and implementation of codes, regulations or incentives for building and retrofitting structures in a manner that improves resilience against flooding.
- Alert communities most vulnerable to flooding and target such training and outreach to them.
- Get more jurisdictions participating in NFIP as well as Community Rating System (CRS).
- Create guide with options and methods for communities to manage deed-restricted flood buyout properties so they become assets instead of liabilities.
- Help and encourage jurisdictions in acquiring property subject to flooding, including helping them know what to do with such properties.
- Provide training or outreach to communities with repetitive loss properties, including information about measures which may be used to reduce future damage.
- Mitigate flooding of buildings by elevating buildings (to the 0.2% annual chance flood elevation or 2+ feet above BFE), flood-proofing, constructing non-levee embankments (e.g. berms) on the building property, or acquiring and removing buildings on flood-prone properties.
- Advocate for flood mitigation in watershed plans by having city officials and county emergency management participate in development and implementation of such plans
- Work with IDNR and IDALS to ensure, as Section 319 and other watershed plans are developed in conjunction with their staff, that flood impact data is shared and local emergency management personnel in subject watershed areas are informed of watershed planning initiatives.
- Encourage cities, counties, levee districts and others to participate in watershed management authorities or other coalitions to study and recommend mitigation solutions for flood issues. Offer technical assistance or outreach to jurisdictions about how to coordinate watershed-wide implementation of small projects for a greater cumulative effect (such as controlling tile drain flow rates to not only reduce flooding but also drought impacts).
- Identify public buildings that are in the special flood hazard area (SFHA), notify their owners, and tell owners that to be eligible for grant opportunities for retrofitting such buildings they need to include such a mitigation action in their local hazard mitigation plan.
- Elevate or otherwise protect wastewater lift stations.
- Reduce damage from flooding and erosion through stream channel improvement projects.
- Encourage a comprehensive planning approach that fully considers watershed approach or green infrastructure options, but where they are not very cost effective or appropriate, mitigate flood damage to structures or public facilities through retrofitting bridges, elevating roads, building or reconstructing levees (in accordance with standards of 44 CFR 65.10), or installing culverts or other stormwater system improvements.

- Implement green infrastructure (including permeable pavement, detention basins, and methods that increase infiltration or detention) in cities.
- Mitigate flooding with a watershed approach by putting in practices upstream of cities that detain water and/or increase infiltration (e.g. wetlands, terraces, oxbows, other basins, perennial cover, series of WASCOBs).
- Educate the public about flood preparation and avoidance.
- Establish or improve warning and alert systems (e.g. sirens).
- Discuss flood mitigation opportunities with the Iowa Water Resources Coordination Council and Iowa Watershed Planning Advisory Council at least annually. Consider outreach to other stakeholders/groups that work in watershed management.
- Provide example standards and guides, including the Iowa Stormwater Management Manual, to local jurisdictions that promote green infrastructure practices and measures that direct water away from structures.
- Develop watershed plans, hydrologic and hydraulic studies, or studies of issues related to groundwater or erosion that analyze hazard mitigation options.
- Encourage programs for residential properties (like Bee Branch Healthy Homes Resiliency Program) that implement on-site stormwater management practices (such as gutters, drains, concrete work, and landscaping that direct water away from homes).
- Prioritize eastern Iowa flood mitigation projects for grant funding.
- Develop a comprehensive, statewide flood mitigation strategy that considers flood buy-outs, watershed approach flood mitigation, levees and other solutions and outlines where and under what conditions these different strategies are best applied.
- Provide technical assistance to help communities understand their flood issues to explore alternatives for mitigation.
- Increase floodwater storage through floodplain or streambank restoration.
- Put in impervious manholes, pumps, or backflow prevention, or similar small-scale flood protection projects.

3.3.4. Severe Winter Storms

A. General Description

Severe winter weather conditions that can affect day-to-day activities include blizzard conditions, heavy snow, blowing snow, freezing rain, heavy sleet, and extreme cold. Winter storms are common during the months of October through April in Iowa.

The various types of severe winter weather can cause considerable damage. Winter storms can immobilize transportation systems, down trees and power lines, collapse buildings, and cause the loss of livestock and wildlife. Blizzard conditions are winter storms lasting at least three hours with sustained winds of 35 mph or more, reduced visibility of a quarter mile or less, and white out conditions. Heavy snows of more than six inches in a 12-hour period, or freezing rain greater than one-quarter inch accumulation, can cause hazardous conditions by slowing or stopping the flow of vital supplies as well as disrupting emergency and medical services.

Loose snow begins to drift when wind reaches a speed of 9 to 10 miles per hour under freezing conditions. The potential for drifting is substantially higher in open country than in urban areas where buildings, trees, and other features obstruct the wind.

Ice storms have resulted in fallen trees, broken tree limbs, downed power lines and utility poles, fallen communications towers, and impassable transportation routes. Severe ice storms have caused power outages over large areas of Iowa. Severe storms have also shut down or made roadways impassable, and as a result, have prevented first responders from providing emergency services to people in need of assistance.

Cold temperatures can cause hypothermia especially when combined with wind chills that further reduce the perceived air temperature to exposed skin. Hypothermia can affect anyone, but the elderly and the very young are particularly vulnerable. Water pipes, livestock, fish, wildlife, and pets are also affected by the dangers of extremely cold weather.

B. Previous Occurrences

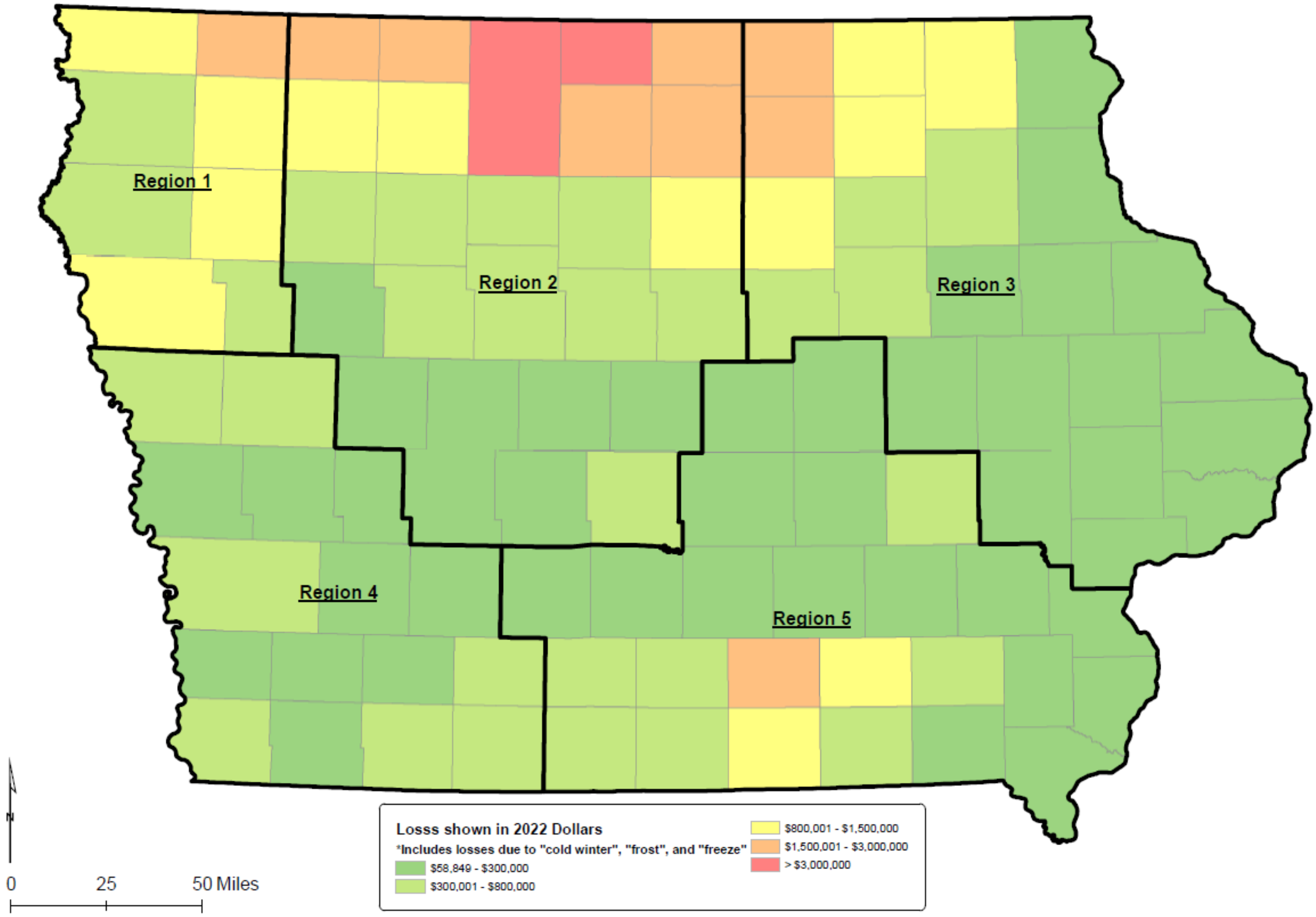
Iowa continues to have a host of winter-related events cataloged in the National Centers for Environmental Information. The NCEI database included these winter-type events for Iowa for November 2017- October 2022:

- 84 winter weather
- 77 winter storm
- 24 blizzard
- Seven ice storm
- 23 heavy snow
- 42 cold/extreme cold/wind chill events.

Some of these events may overlap, but it is clear that in Iowa a variety of winter weather-related hazards are commonplace. In Iowa, there are cases where deaths have been attributed to cold temperatures or blizzards.

Statewide, these events resulted in an estimated $516,800 in property damage, 10 indirect deaths, three direct deaths, and 16 indirect injuries, according to the NCEI Storm Events Database. Though not reported in the NCEI database, winter weather events have also resulted in much crop damage. The map below illustrates the value of such crop damage, based on crop insurance claims.

Inflation-adjusted crop insurance claims due to Winter Storms from 1989 to July 2022.



Eight winter-storm-related Presidential Disaster Declarations for major disaster have been declared in Iowa since 1991. The first declaration related to winter storms which occurred in 1991 resulting from an ice storm that affected 16 counties. Extensive damage occurred to power lines, including the collapse of numerous high-tension towers in north-central Iowa. The second declaration occurred in 1997 resulting from a severe winter storm that affected 13 counties. In 2007, the third declaration on March 14 affected 48 counties and the fourth declaration on March 30 affected 23 counties with five counties included in both declarations. These declarations resulted from a major winter storm with ice and heavy snow combined with strong winds gusting to 50-55 mph causing blizzard conditions. Some areas in Iowa received 16 inches of snow, and coupled with the strong winds, it caused already weakened ice-covered power lines to crumble and interstate highways to be closed due to drifting snow. This situation left approximately 250,000-plus Iowa citizens without electricity for more than 10 days. In central Iowa, one county had 20 miles of downed power poles that snapped due to the power lines being coated with inches of ice coupled with the strong winds, with high-tension towers also collapsing. Due to the severity of the winter blizzard, the governor signed a governor's proclamation of disaster emergency for all 99 counties in Iowa. Another disaster was declared in January of 2008, affecting 30 counties in southern Iowa. The remaining two Presidential Disaster Declarations occurred in late February 2010, impacting 27 counties, and in early March of 2010, impacting 27 counties in western Iowa. The most recent Presidential Disaster Declaration for a winter storm in Iowa occurred in April of 2013 in five northwestern counties.

Although winter weather has not resulted in Presidential Disaster Declarations in Iowa in the last five years, the state has experienced several severe winter storms in that time. The Des Moines office of the National Weather Service (NWS) describes a few of these on their "Event Summaries" page of their website[64], including the following events:

- In 2019 widespread snowfall amounts of 5 to 15 inches fell across the northwest half of Iowa on February 23-24. In addition to the falling snow, very strong northwest winds of 30 to 45 mph caused widespread blizzard conditions from the late evening of the 23rd through much of the 24th.
- On April 16, 2020 a storm came through Iowa bringing wet, sticky snow to central and southern Iowa. The two most southern tier of counties saw 8-12 inches, with some isolated areas experiencing higher amounts.
- January 25-26 of 2021 saw a major winter storm hit Iowa, with several reports of 8 to 14 inches of snowfall over much of central Iowa. Strong northeast winds caused near whiteout conditions at times leading to treacherous driving conditions.

C. Location, Probability and Intensity

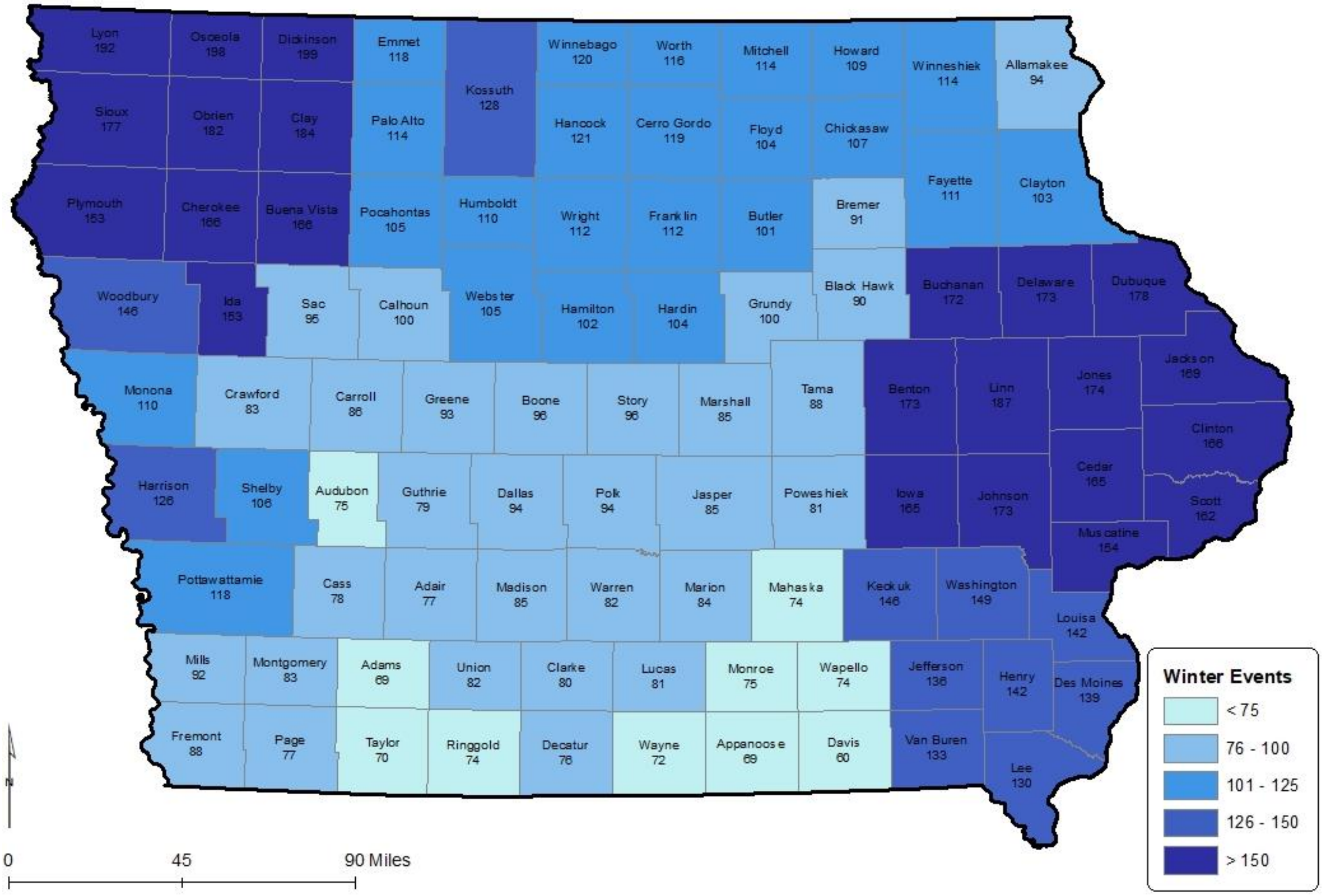
Past history has shown that a 6-inch snowfall or more from one storm occurs only in 49 percent of Iowa winters, while a large winter storm event of 10 inches or more will occur about once every three years.

According to the National Oceanic and Atmospheric Administration (NOAA) winter storms regularly move easterly and use both the southward plunge of arctic cold air from Canada and the northward flow of moisture from the Gulf of Mexico to produce heavy snow and sometimes blizzard conditions in Iowa. Most Iowa counties can expect two or three winter storms a season with an extreme storm every three to five years on average. The entire state is susceptible to severe winter weather; though snow may be slightly more common in the northern part of the state, the southern part may experience more ice, which is just as severe.

The map below shows the number of winter storm events by county. This does not account for severity, but the frequency shows eastern central, southeastern, and northwestern Iowa having the greatest number of winter storm events, while north central and northeastern Iowa have a moderate amount. Central and southeastern Iowa have relatively fewer winter storm events.

[64] https://www.weather.gov/dmx/events

Winter Storm Events by County, 1996 – 2022. Number of NCEI Storm Events of these types: Blizzards, Ice Storms, Heavy Snow, Winter Weather, Extreme Cold / Wind Chill, Cold/Wind Chill



Recent analysis of climate change trends has shown that there is the potential that future occurrences of extreme cold/wind chill accompanying winter storms should decrease. Instead, higher winter temperatures will bring rain rather than snow. There is also evidence that there is an increase in precipitation in winter and spring across the Midwest as well as an increase in the intensity of such storm events.

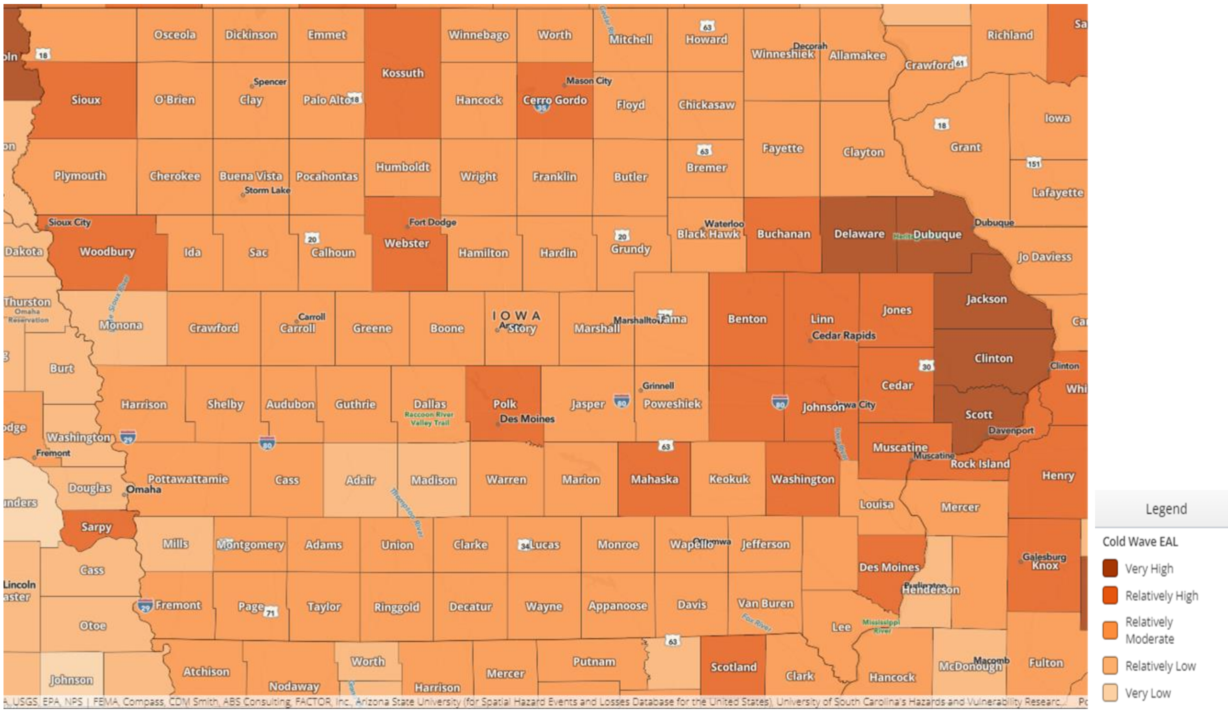
D. Summary of Vulnerability and Problem, and Identification of Possible Actions to Mitigate Problem

The next three maps illustrate areas expected to experience the worst damage from winter storms. The maps were developed from analysis provided by FEMA through the National Risk Index (NRI). The first map shows expected annual losses (EAL) from cold waves, which the NRI defines as a rapid fall in temperature within 24 hours and extreme low temperatures [65] for an extended period. According to the NRI analysis, the most affected counties for cold waves are Dubuque, Scott, Delaware, Clinton, and Jackson counties. The Cold Wave EAL for these counties is over $1 million each, with Dubuque and

[65] Temperatures classified as a Cold Wave are dependent on the location and defined by the local NWS weather forecast office.

Scott counties having expected annual losses greater than $2 million each. The Cold Wave EAL for the entire state, inclusive of all counties, is over $28 million (as of December 2022, per the FEMA NRI[66]).

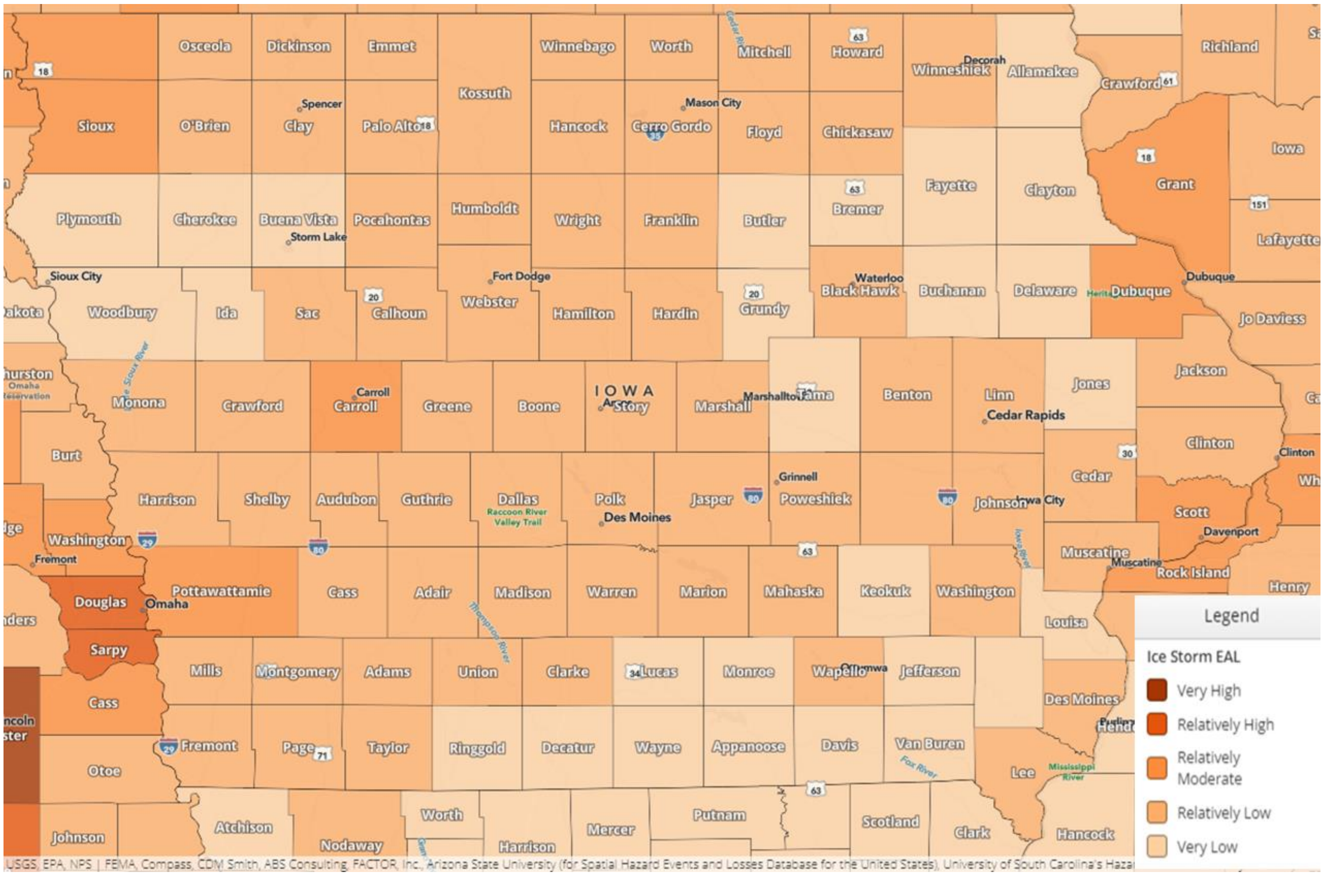
Cold Wave EAL



The next map shows how counties compare in their EALs for ice storms. An ice storm is a freezing rain situation (rain that freezes on surface contact) with significant ice accumulations of 0.25 inches or greater. The NRI analysis reveals that the counties expected to have the highest losses from ice storms are Dubuque, Sioux, Scott, and Pottawattamie counties. These counties have EALs of over $300,000 each. Dubuque has the highest EAL, being $436,037. The Ice Storm EAL for the entire state, inclusive of all counties, is $4,980,971 (as of December 2022, per the FEMA NRI).

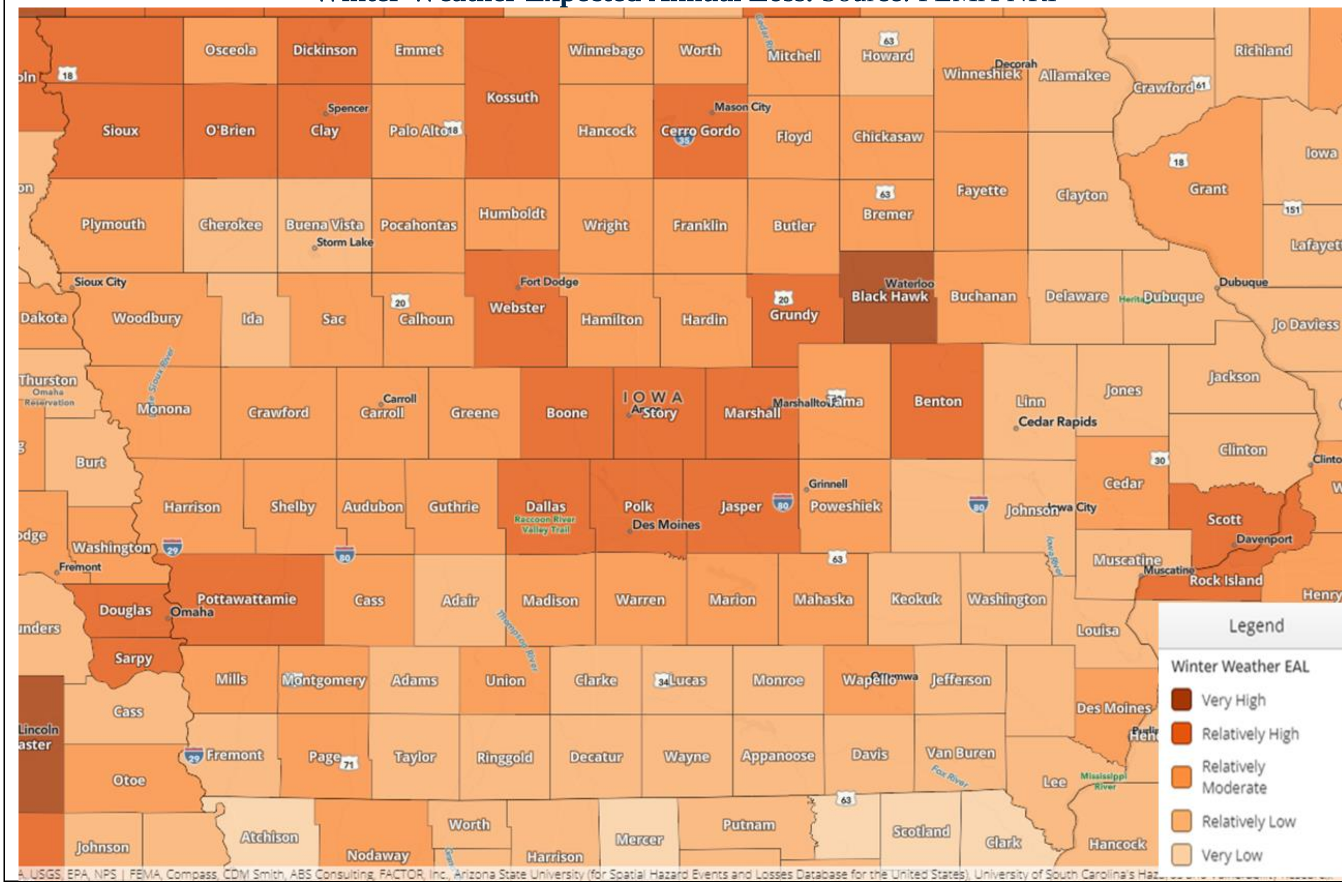
[66] https://hazards.fema.gov/nri/map

Ice Storm Expected Annual Loss. Source: FEMA NRI



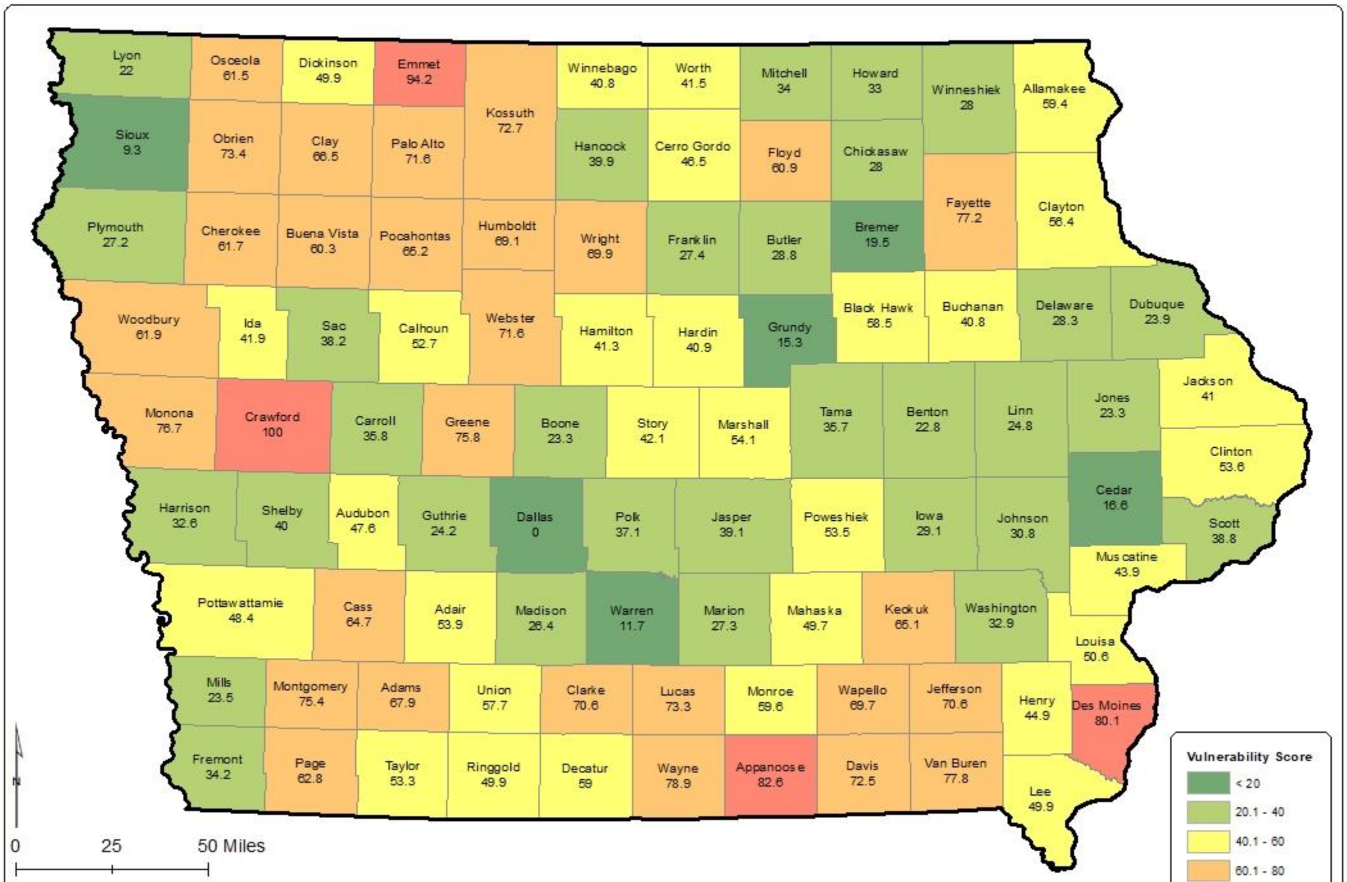
The following map shows how counties compare in their EALs for what the NRI calls Winter Weather. Winter Weather consists of winter storm events in which the main types of precipitation are snow, sleet, or freezing rain. According to the NRI analysis, the counties expected to be most vulnerable to losses are Black Hawk, Dickinson, Sioux, Story, Polk, and Dallas counties. These counties have EALs of over $400,000 each. Black Hawk County has the highest EAL, at $1,064,075, and is double that of any other county except Story County (whose EAL is $599,549). The Winter Weather EAL for the entire state, inclusive of all counties, is $12,285,703 (as of December 2022, per the FEMA NRI).

Winter Weather Expected Annual Loss. Source: FEMA NRI



The above maps illustrate which counties are most vulnerable to severe winter weather in terms of dollar losses. Vulnerability can also be considered in regards to various social factors as well. The map below illustrates an analysis that estimates social vulnerability to severe winter storms. This analysis is largely the same as that used for excessive heat, and hail & lightning, and focuses on barriers to understanding or responding to these emergency events, whether because of age (children or older populations), disability (physical and mental), financial constraints, limited English proficiency, access to a vehicle, or living alone. The analysis indicates that the most vulnerable counties are Crawford, Emmet, Appanoose, and Des Moines.

Social Vulnerability to Winter Weather, Hail, and Lightning



Factors include poverty, disability, age, age 65+ living alone, vehicle access, & English proficiency
Data source: US Census Bureau ACS (2021)

As illustrated in the above EAL maps for Cold Wave, Ice Storm and Winter Weather, economic losses can be high with severe winter storms. Actions to mitigate such economic losses are important, but mitigation actions must also address the more social factors and human suffering that can come from these hazards. The following are some possible actions that could address either the economic losses, the social suffering, or both:

1. Electrical utility retrofit/hardening
2. Establishing warning systems that inform the public
3. Installation of backup power generators at critical facilities
4. Improving awareness of hazard risks and ways to prevent or reduce impacts
5. Promotion of NOAA all-hazards weather radios
6. Adoption and better enforcement of, or otherwise encourage the use of, building standards in individual jurisdictions and/or statewide

3.3.5. Hail and Lightning from Thunderstorms

A. General Description

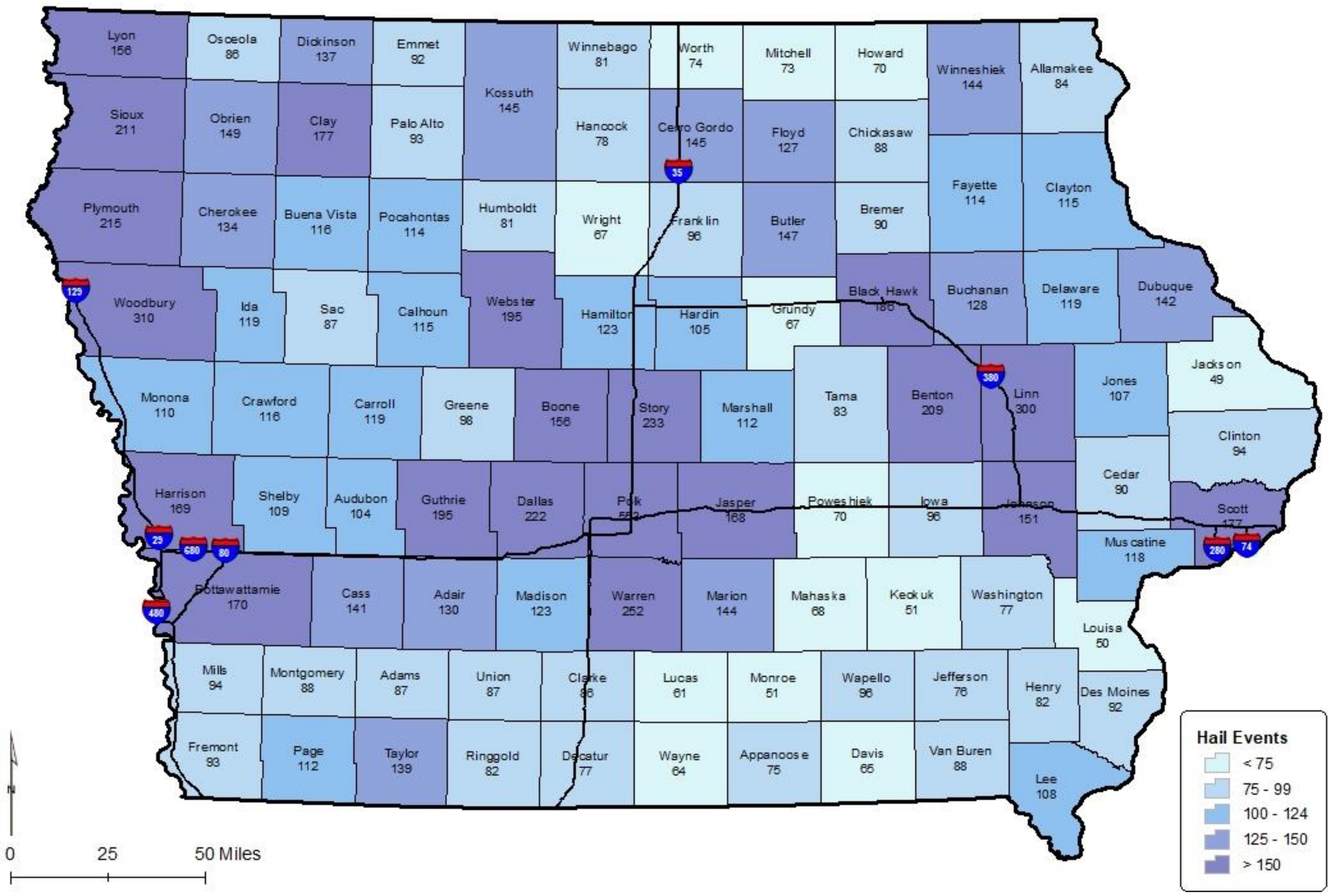
Thunderstorms are common in Iowa and can occur singly, in clusters, or in lines. Thunderstorms can result in heavy rains, high winds (reaching or exceeding 58 mph), tornadoes, or hail. For the purposes of this hazard analysis and risk assessment, the thunderstorm effect of flooding due to rain is primarily analyzed in the profile of flash flood and flood, and the effects of high wind are included in the profile of tornado/high wind. In this profile, the thunderstorms' effects and risks of lightning and hail are those primarily analyzed and assessed.

Lightning is an electrical discharge that results from the buildup of positive and negative charges within a thunderstorm. When the buildup becomes strong enough, lightning appears as a "bolt" or flash of light that occurs within the clouds or between the clouds and the ground. A bolt of lightning reaches temperatures approaching 50,000 degrees Fahrenheit in a split second. This rapid heating, expansion, and cooling of air near the lightning bolt creates thunder.

Hailstorms are a product of a severe thunderstorm in which pellets or lumps of ice (of most concern when greater than 1 inch in diameter) fall with rain. Hail is produced in many strong thunderstorms by strong rising currents of air carrying water droplets to a height where freezing occurs, the ice particles grow in size until they are too heavy to be supported by the updraft and fall back to earth. Hail can be smaller than a pea or as large as a softball and can be very destructive to plants and crops. Pets and livestock are particularly vulnerable to hail.

B. Previous Occurrences

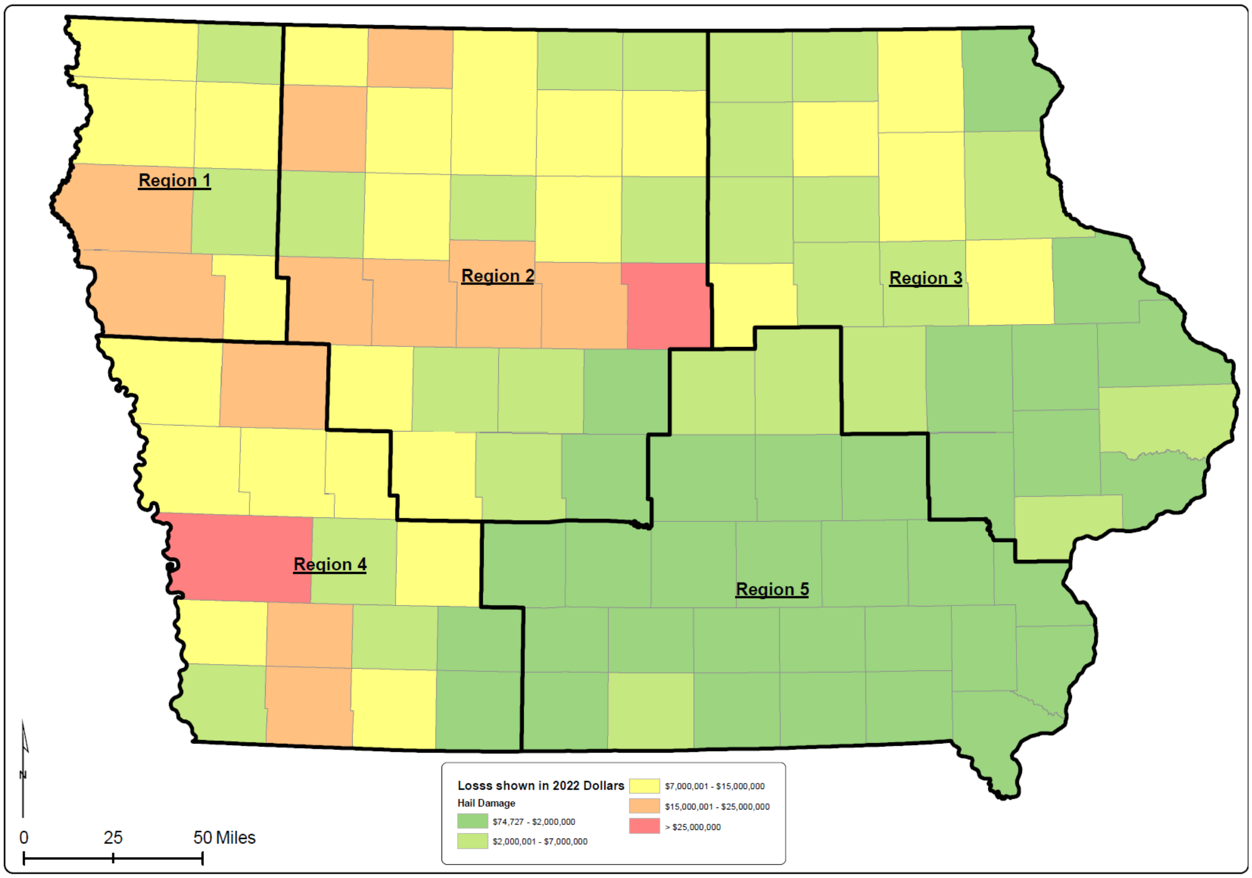
Hail Events, 1996-2022. Source: NCEI Storm Events Database.



The accompanying map shows the number of occurrences of hail storms in each county in Iowa since 1996. More recently, in the five-year period between November 2017 and October 2022, the NCEI Storm Events Database lists 278 hail events and more than 108 heavy-rain events that have impacted Iowa. Some storms affect multiple counties, but the data for this five year period has been sorted to count each "episode" only once. Thunderstorms may occur singly, in clusters, or in lines, so it is also possible that several thunderstorms may affect the same area in the course of a few hours. In addition, the NCEI database includes 31 lightning events for that five year period, but it should be noted that only lightning events that result in damages are recorded in the NCEI database. The NCEI data is not perfect, but represents best available data. Previous occurrences of tornadoes or severe wind related to thunderstorms are discussed further in the hazard profile for tornado/wind. Likewise, flooding events related to thunderstorms are detailed in the flood hazard profile.

As mentioned, lightning events are typically only reported in NCEI when they cause significant damage or injury. According to NCEI, lightning events since 1996 have caused 5 direct injuries and estimated losses totaling to $1,948,000 in property damage. No lightning-related deaths are reported in NCEI as having occurred during this period.

Inflation-Adjusted Crop Insurance Claims due to Hail (1989-2022)



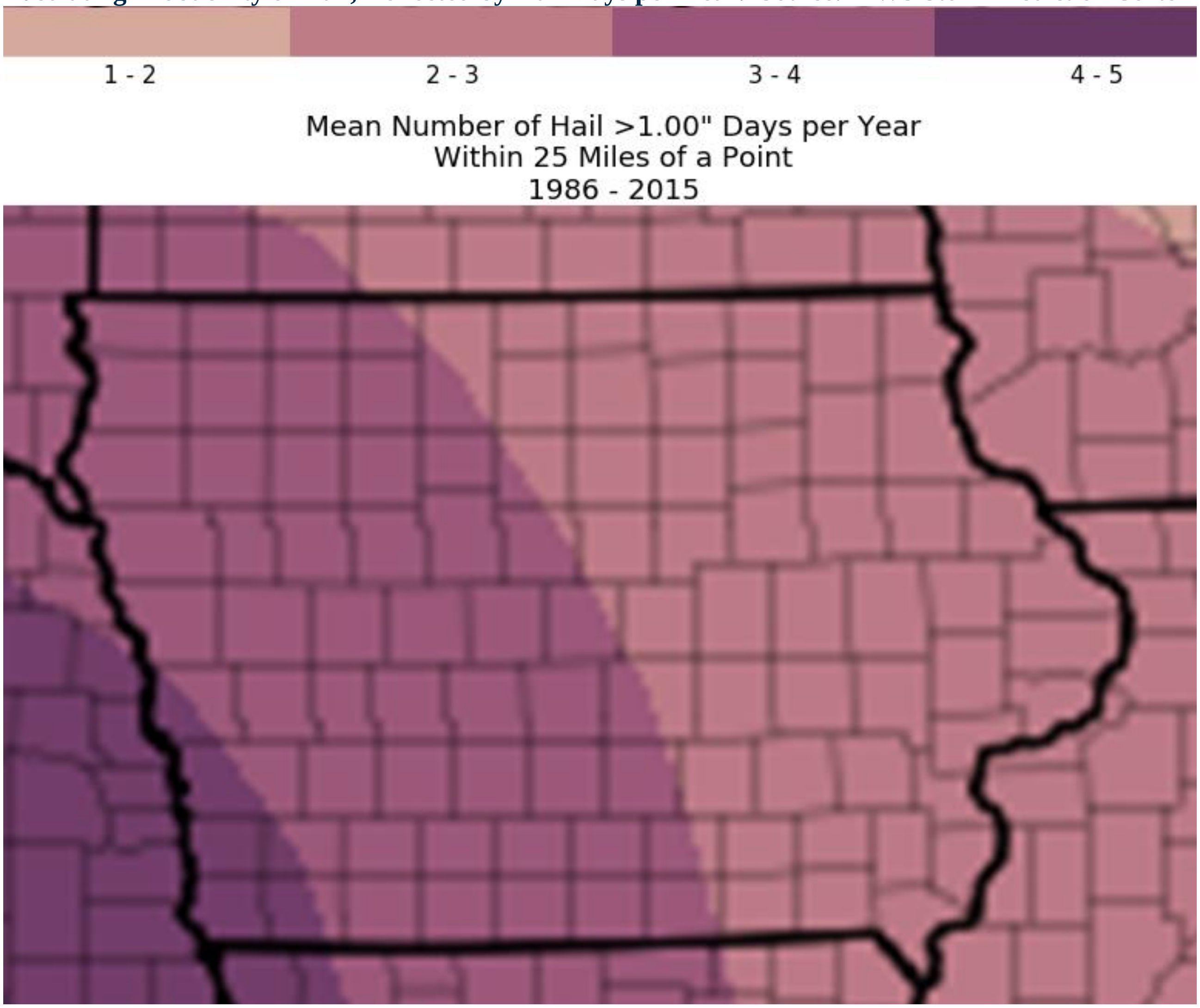
The majority of hail events recorded in the NCEI do not note any estimated damages or injuries, but the few that do cause significant losses. In just the recent five year period between November 2017 and October 2022, hail events have caused estimated losses totaling to $1,780,000 in property damage, and $8,487,100 in crop damages. No hail-related deaths or injuries are reported in NCEI as having occurred during this period. Besides the NCEI, the USDA Risk Management Agency (RMA) has data on crop losses from hail, which is shown on the accompanying map.

As mentioned, thunderstorms are hazards unto themselves but can cause other hazards such as flash flooding, river flooding, and tornadoes/windstorms.

C. Location, Probability and Intensity

Lightning and hail events can and do occur in any and all of the counties across the state with almost equal likelihood.   As shown in the map and descriptions above, Iowa experiences many hail and lightning events every year.

Illustrating Probability of Hail, Reflected by Hail Days per Year. Source: NWS Storm Prediction Center[67]



Data on the probability and frequency of hailstorms is limited, but research indicates that most any point in Iowa can expect, on average, two to four hailstorms a year (source: Changnon, Stanley A., David Changnon and Steven D. Hilberg, *Hailstorms Across the Nation: An Atlas about Hail and Its Damages*, published by Illinois State Water Survey, 2009). While this average is based on recorded historical data from 1950-2005, the adjoining map illustrates the number of severe hail days per year for a more recent period (1986-2015) is very similar. It shows that southwest Iowa has had more hail days per year than the rest of the state.

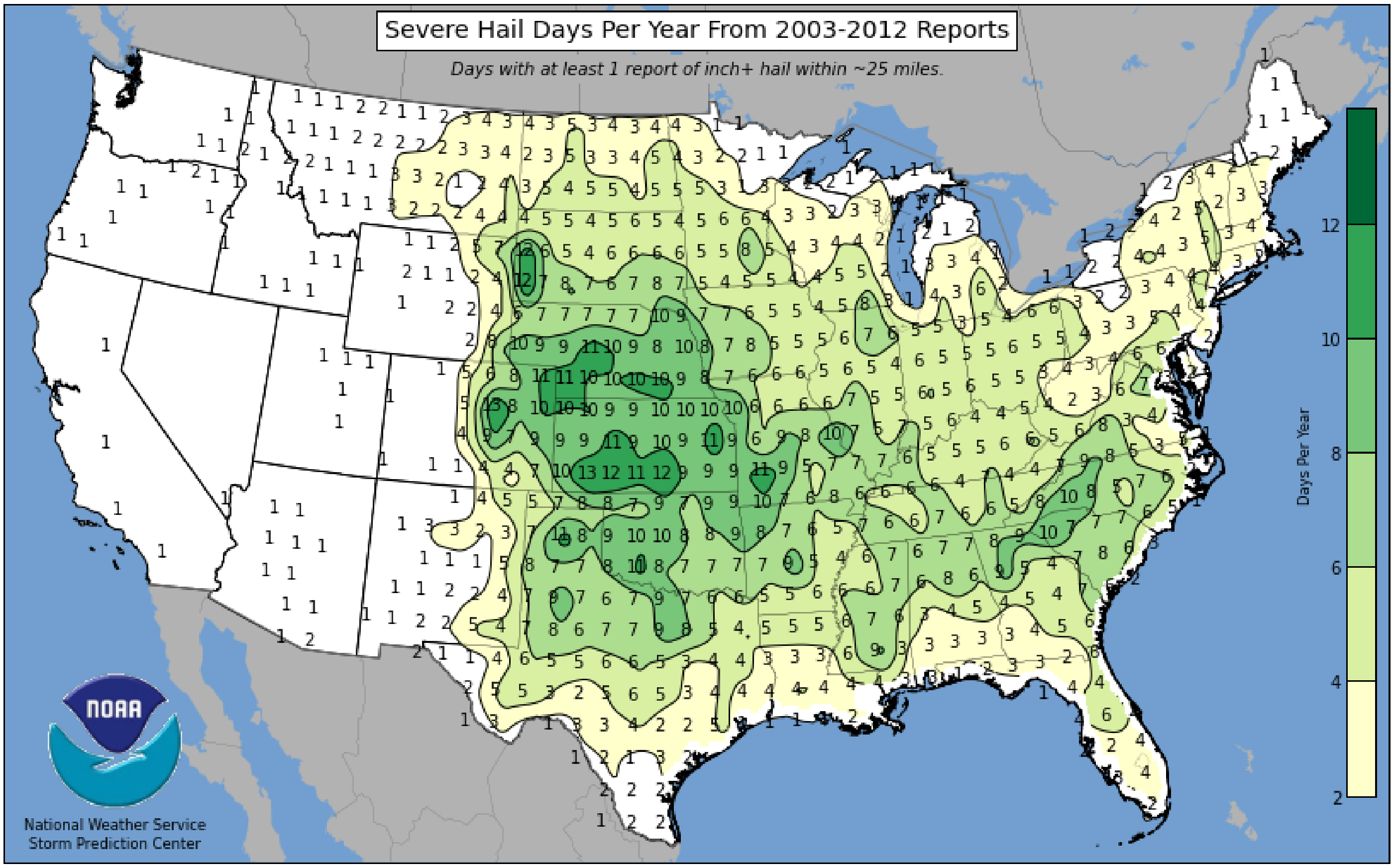
The next map is for only a ten-year period, and appears to show that during this more recent period the number of hail days per year has increased. At this point there is probably not enough data to be able to determine if this indicates a trend, better reporting of hail events, or perhaps just an anomaly that is not statistically significant. It should be noted, however, that with recent trends of higher temperatures during

[67] https://www.spc.noaa.gov/wcm/climo/newhail.png

the summers and higher humidity, thunderstorms with hail and lightning may increase in occurrences and severity.

Whether or not occurrences of hail are increasing, these different maps consistently show that southwest Iowa has more incidence of hail.

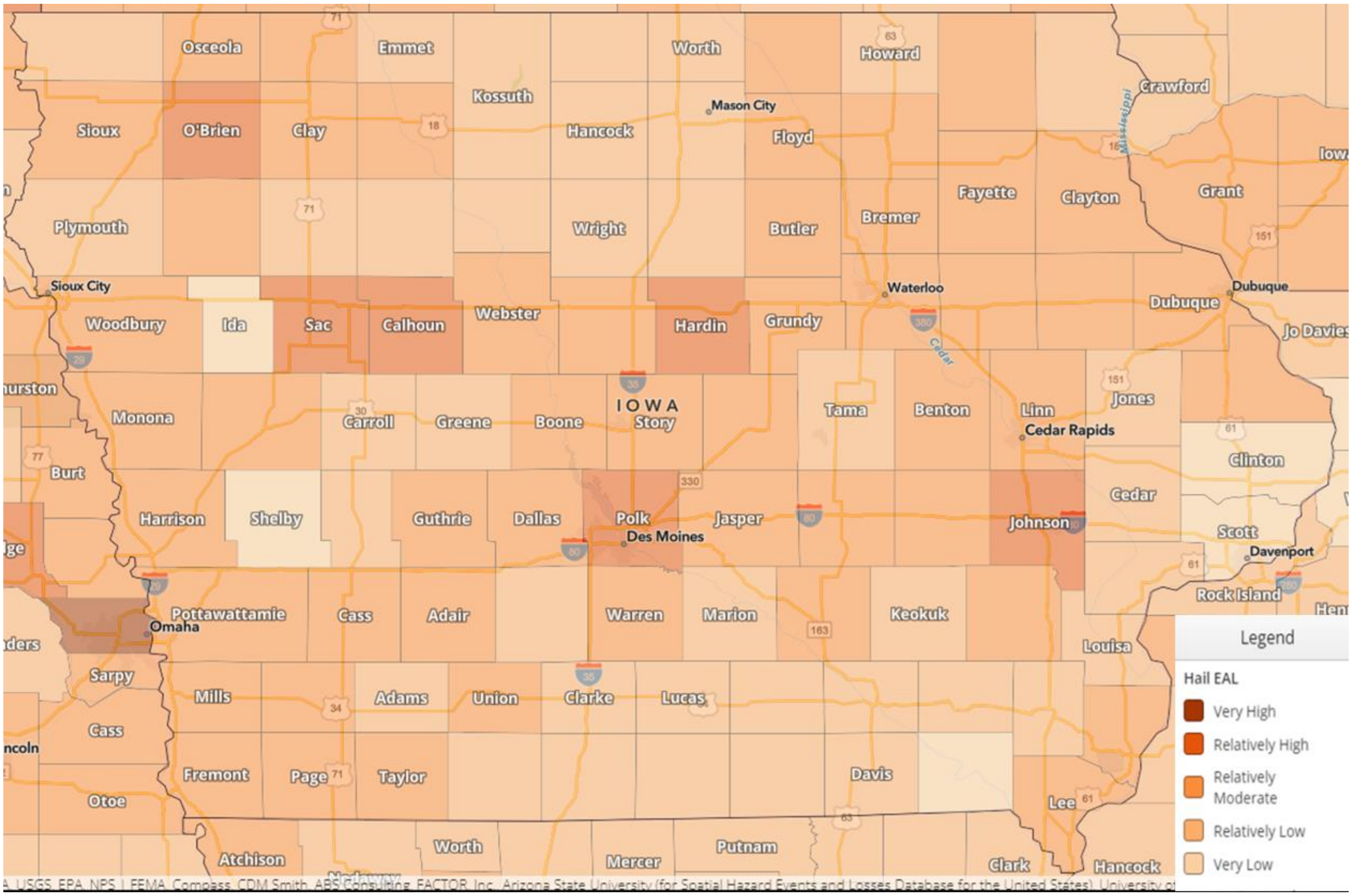
Days Per Year of Hail. Source: National Weather Service Storm Prediction Center.



D. Summary of Vulnerability and Problem, and Identification of Possible Actions to Mitigate Problem

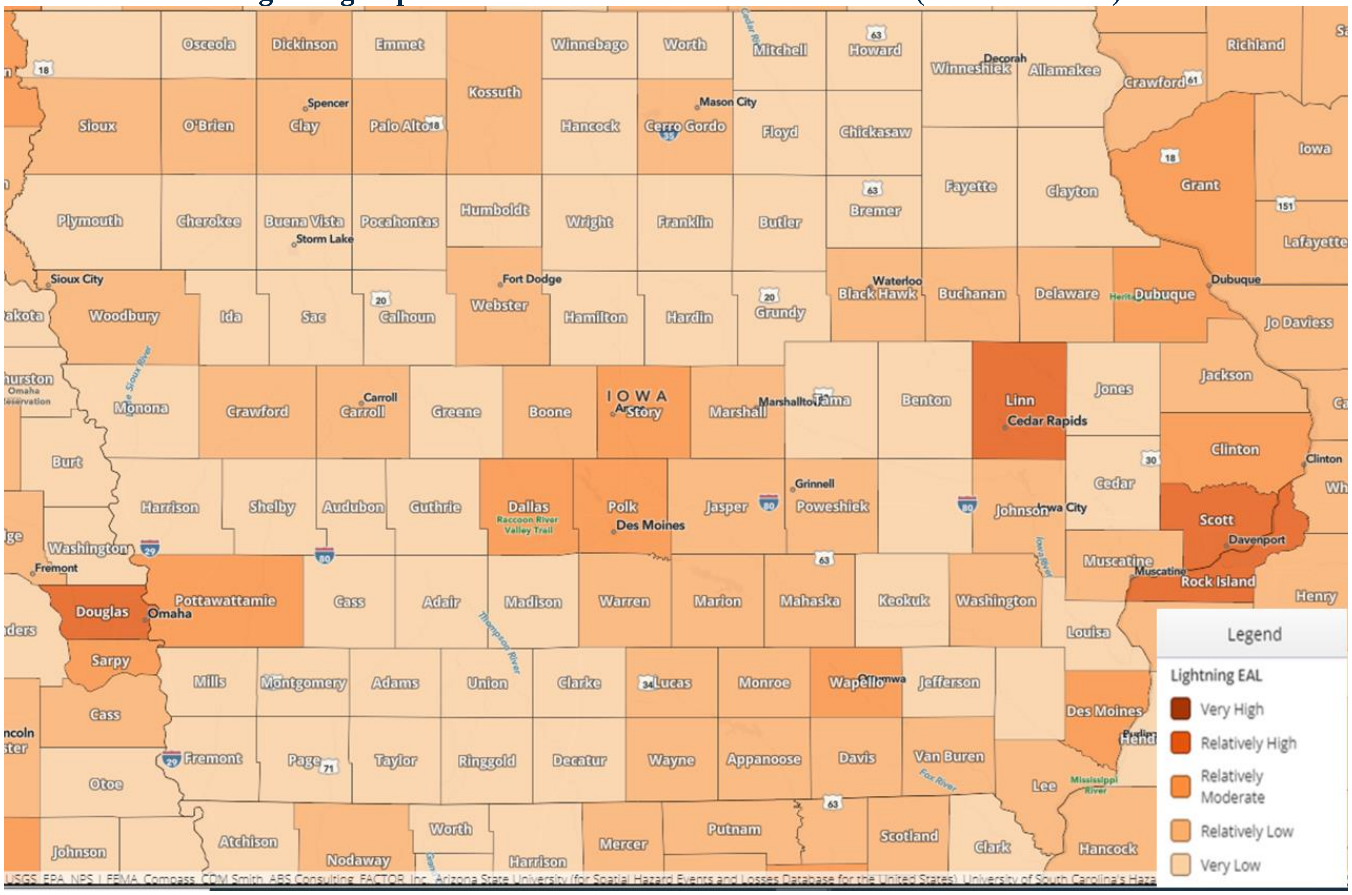
While the map above shows that, on average, more hail days per year occur in western Iowa, the analysis from FEMA's NRI reveals that expected annual loss (EAL) from hail is not highest in the western counties. Johnson County, with structures of high value susceptible to hail damage, has the highest EAL of over $3.1 million. Polk County comes in second with an EAL over $2.6 million. The counties with Hail EALs of $1 million to $2 million are Calhoun, Des Moines, Hardin, Linn, O'Brien, Sac and Webster. The NRI considers both property loss and crop loss in their EAL estimations, which helps to explain why there is a mix of both urban and rural counties with EALs over $1 million. The Lightning EAL for the entire state, inclusive of all counties, is $46,316,850 (as of December 2022, per the FEMA NRI).

Hail Expected Annual Loss. Source: FEMA NRI (December 2022)



The following map shows how counties compare in their EALs for Lightning. According to the NRI analysis, the counties expected to be most vulnerable to lightning are Linn and Scott counties. These counties have EALs of $450,000 to $500,000. Counties with EALs between $200,000 and $260,000 are Dubuque, Polk, Pottawattamie, and Wapello. The Lightning EAL for the entire state, inclusive of all counties, is $4,761,367 (as of December 2022, per the FEMA NRI).

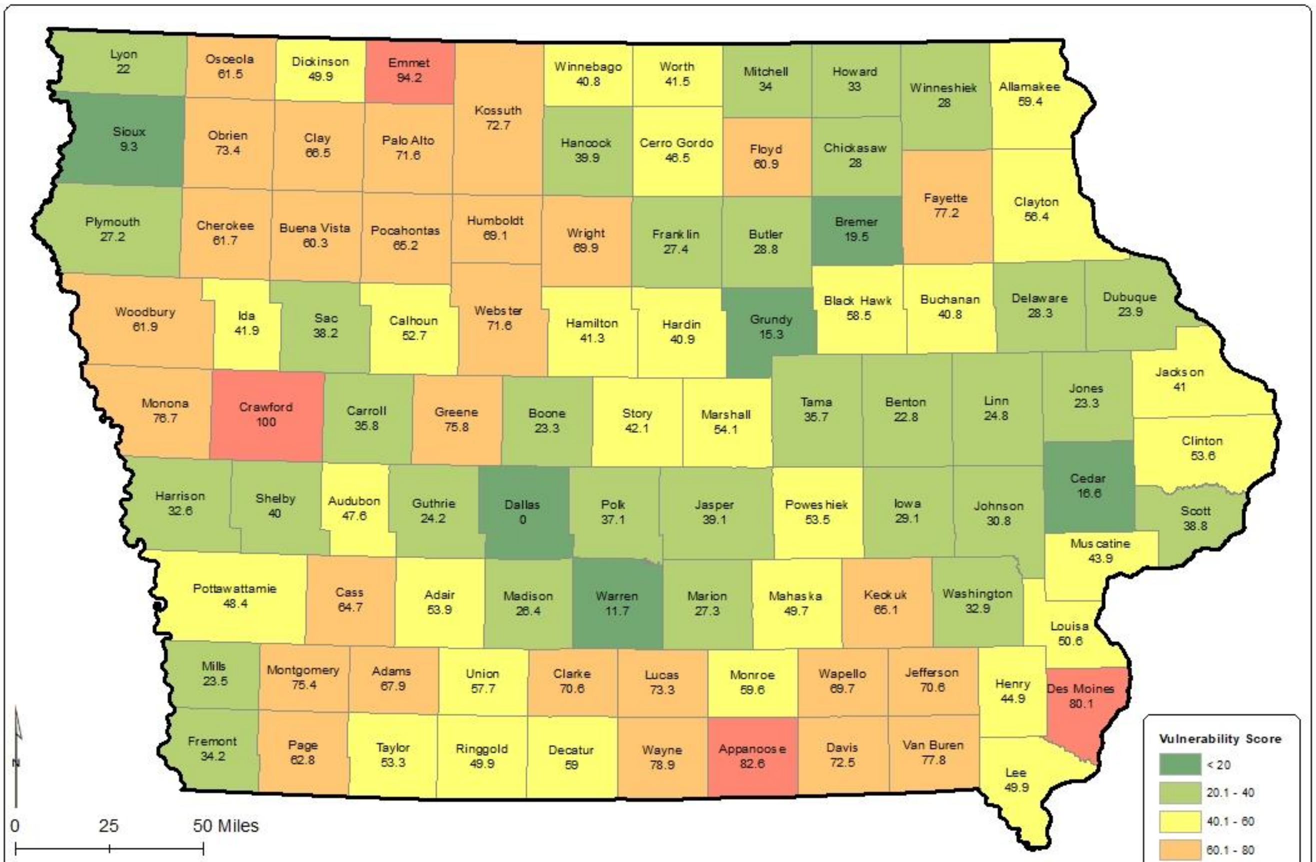
Lightning Expected Annual Loss. Source: FEMA NRI (December 2022)



The above maps illustrate which counties are most vulnerable to lightning and hail in terms of dollar losses. Vulnerability can also be considered in regards to various social factors as well. The map below illustrates an analysis that estimates social vulnerability to hail and lightning (as well as severe winter storms, discussed previously). This analysis is largely the same as that used for excessive heat and focuses on barriers to understanding or responding to these emergency events, whether because of age (children or older populations), disability (physical and mental), financial constraints, limited English proficiency, access to a vehicle, or living alone. The analysis indicates that the most vulnerable counties are Crawford, Emmet, Appanoose, and Des Moines.

Both people and property are vulnerable to hail and lightning, and actions should be taken to reduce that vulnerability wherever it is found in Iowa, whether in the east or west, or in big cities or small towns. Some methods for mitigating the effects of these storms include:

Social Vulnerability to Winter Weather, Hail, and Lightning



Factors include poverty, disability, age, age 65+ living alone, vehicle access, & English proficiency
Data source: US Census Bureau ACS (2021)

- Proper grounding for structures that need it, and other structural improvements. Jurisdiction building codes could be improved and/or adopted to address these issues
- Produce and provide educational and awareness materials to inform people about how they should prepare for and respond to thunderstorms, especially what to do when outside
- Build shelters or safe rooms at parks and other outdoor areas where people may be
- Encourage people to get weather radios
- Harden and retrofit electrical lines and equipment

3.3.6. Excessive Heat

A. General Description

Conditions for extreme heat are defined by summertime weather that is substantially hotter and/or more humid than average for a location at that time of year. Definitions vary by Weather Forecast Office, but the NWS Weather Forecast Office in Des Moines defines excessive heat as heat index greater than 110 degrees Fahrenheit for two or more consecutive days. The heat index is a number in degrees Fahrenheit that tells how hot it really feels when relative humidity is factored into actual air temperature. Exposure to full sunshine can increase the heat index by at least 15 degrees. The chart below shows the heat index values when both humidity and temperature are considered. It also shows the likelihood of heat disorders with prolonged exposure to or strenuous activity in such conditions.

NWS Heat Index — Temperature (°F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution | Extreme Caution | Danger | Extreme Danger

Under extreme heat conditions, the National Weather Service can issue either a heat advisory or an excessive heat warning, as described below

1. ***Heat advisory***

A heat advisory is issued when a heat index of 100 degrees Fahrenheit or higher is expected for a period of three hours or more. A heat advisory shall be continued through the overnight hours, following a day with excessive heat, if the heat index is not expected to fall below 75 degrees Fahrenheit. A heat advisory can be issued for a heat index less than 100 degrees Fahrenheit when the cumulative effect of successive days of near advisory-level heat leads to potentially life-threatening conditions.

2. ***Excessive heat warning***

An excessive heat warning is used when a heat index of 105 degrees Fahrenheit or higher is expected for a period of three hours or more. An excessive heat warning shall be continued through the overnight hours, following a day with excessive heat, if the heat index is not expected to fall below 75 degrees Fahrenheit. An excessive heat warning can be issued for a heat index less than 105 degrees Fahrenheit when the cumulative effect of successive days of near warning-level heat leads to life threatening conditions.

With a trend over the last century of rising nighttime temperature lows, and a continuation of the underlying climatological drivers, Iowa can expect more multi-day heat advisories and excessive heat warnings in the future. Days with maximum temperatures above 90°F are projected to occur 2 to 5 times more often by 2050, according to the U.S. Federal Government's Climate Explorer tool, in the 'best case scenario' of RCP 4.5. Days above 100°F, currently occurring once every few years in most of Iowa, are projected to happen several times per year by 2050 in the best-case scenario. Days over 105°F will not be rare either in this scenario. 'Cooling degree days' are projected to nearly double in about 50 years, straining energy systems and increasing chances of blackouts and brownouts (barring adaptation measures).

B. Previous Occurrences

Between 1995 and 2008, Iowa experienced 33 extreme heat events. The NCEI storm events website no longer reports extreme heat events but instead reports excessive heat events. Excessive heat event documentation covers a much shorter time period, but is the best data available. There have been 15 excessive heat events (totaling 23 calendar days altogether) between 2009 and 2017, inclusive. In August 2013, there was an extended heat wave across the eastern portion of the state. In June 2016, there were reports of excessive heat in the northwest corner of the state, and in late July 2016, 66 out of 99 counties were struck again with a heat wave. All 99 counties have experienced an excessive heat event at some point in the last 13 years.

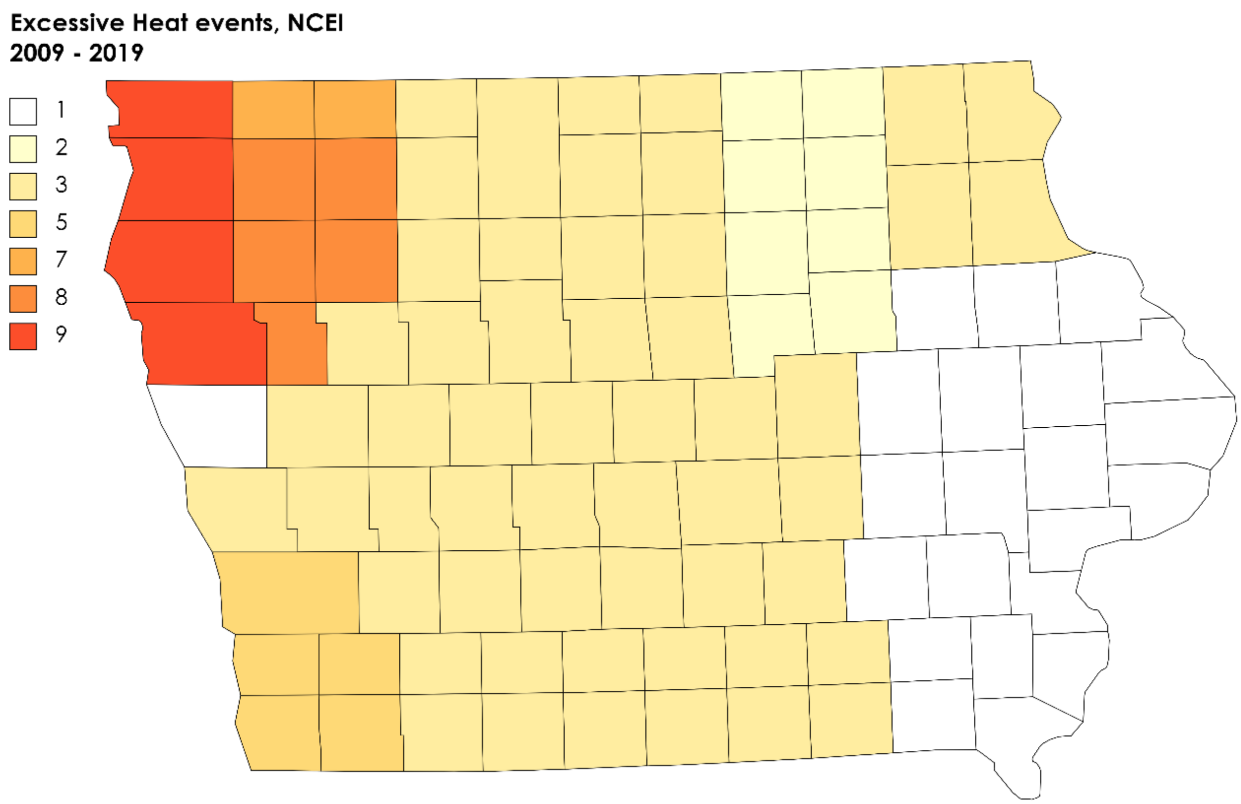
Extreme heat can pose a threat to livestock and crops. High temperatures have been shown to reduce summer milk production, impair immunological and digestive function of animals, and increase mortality of livestock. In July 2011, according to the Iowa Cattlemen's Association, approximately 4,000 cattle died due to extreme heat. In 1995, livestock-related economic losses due to heat stress were estimated to be $31 million in Iowa. Extreme heat can also cause pavement to buckle and rupture. In a typical year, Iowa DOT maintenance equipment operators spend 2,000 to 4,000 hours making temporary repairs of pavement blowups and another 6,000 hours replacing these pavement sections, costing an average of $400,000 annually.

Another repercussion of high heat is the impact on schools. During the heat wave in 2013, school was already back in session. In Marshalltown, schools either dismissed early for the duration of the heat wave or the students were moved to an alternate facility that had functioning air conditioning.

C. Location, Probability and Intensity

While not a lot of data exists to support it (Excessive Heat events have only been tracked since 2009), it appears that northwestern and southwestern Iowa experience more extreme heat events than the rest of the state. Since 2009 most counties in the state had only one or two Excessive Heat events whereas 11 counties in northwest Iowa had seven to nine events and five counties in southwest Iowa had five such events. These are the counties in Iowa that have had more than four Excessive Heat events since 2009 (the number in parentheses is the number of events):

Lyon (9)	Buena Vista (8)	O'Brien (8)	Mills (5)
Plymouth (9)	Cherokee (8)	Dickinson (7)	Montgomery (5)
Sioux (9)	Clay (8)	Osceola (7)	Page (5)
Woodbury (9)	Ida (8)	Fremont (5)	Pottawattamie (5)



In 2011, 78 counties in Iowa experienced an excessive heat event, with a handful experiencing two. This is a normal number of events for most years in the NCEI events database. In 2012 however, numerous counties were hit with four to five excessive heat events in a single year. These counties include Buena Vista, Cherokee, Clay, Dickinson, Ida, Lyon, O'Brien, Osceola, Plymouth, Sioux, and Woodbury. These counties all experienced 7 to 9 excessive heat events from 2009 to 2019, and all are located in northwest Iowa. Fremont, Mills, Montgomery, Page, and Pottawattamie counties all experienced five excessive heat events during this time, all located in the southwest corner of the state. On the opposite end of the spectrum, all counties experiencing only one event are located in the eastern third of the state (with the exception of Monona County).

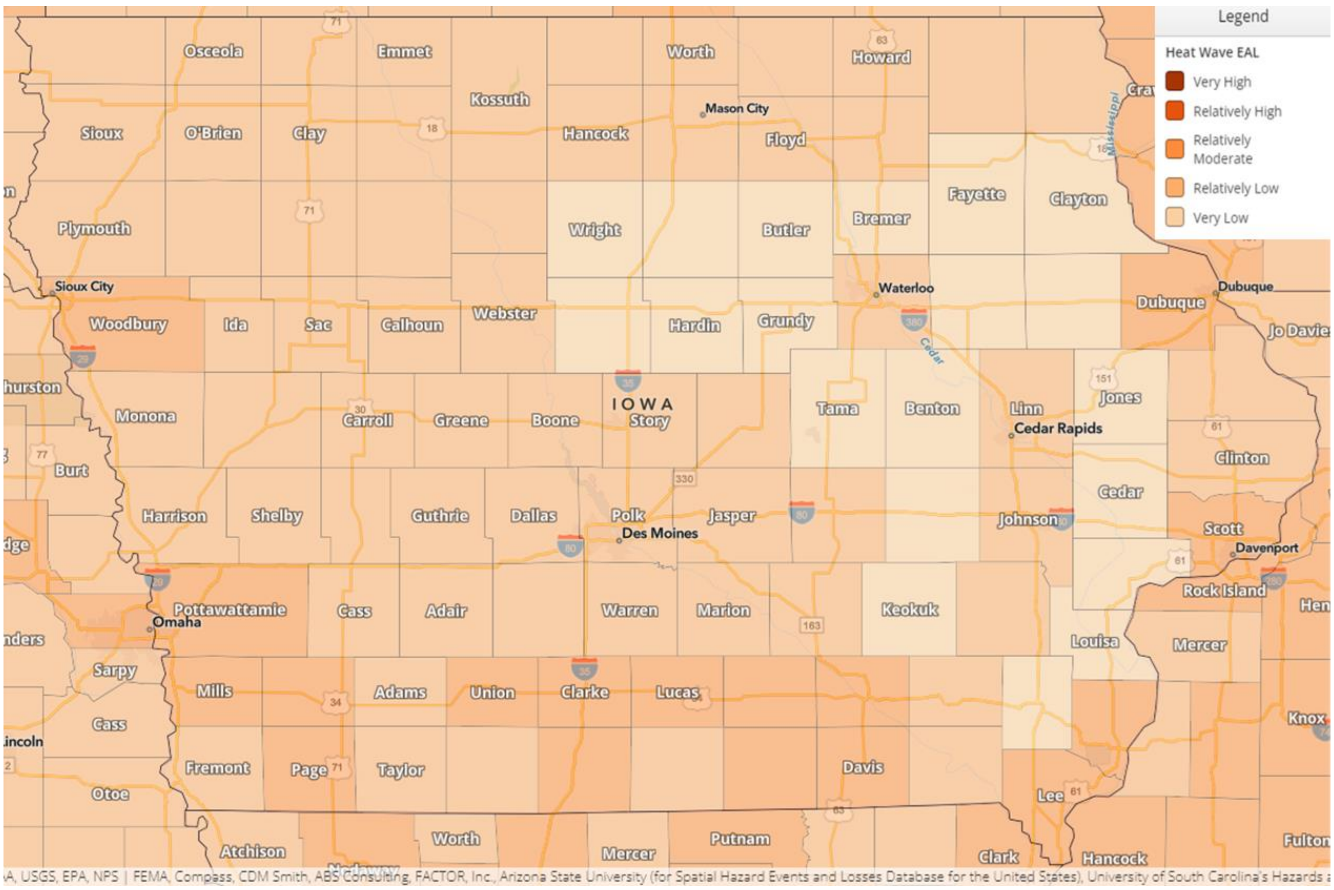
At this point in time, the limited data does not provide much confidence in concluding that northwest or southwest Iowa is more likely than other parts of the state to experience extreme heat incidents. Without the outlier year of 2012, for instance, northwest Iowa would not appear so much worse than the rest of the state. The lack of data also makes it impossible to provide jurisdiction-by-jurisdiction loss estimates. Not only is data only available for the period since 2009, but damage estimates for any of the events are estimates for damages across an entire region. So, for example, the event that was estimated to cost $1,350,000 was a sum total estimate of damages across 51 counties, with no indication on damage estimates for individual counties.

One more factor to consider regarding future vulnerability is that given that summer nighttime temperatures have risen more than daytime temperatures since 1970, and humidity has risen in the same time period, there may be an accompanying increase in the number of extreme heat events in the future. According to the U.S. Global Change Research Program, some experts predict that the incidents of heat waves will be more frequent, more severe, and last longer with greater impact in larger cities.

D. Summary of Vulnerability and Problem

FEMA's National Risk Index provides a means of measuring vulnerability to excessive heat events through its Expected Annual Loss (EAL) factor. By comparing NRI's Heat Wave EALs of counties in Iowa, the counties in the southern part of the state appear most vulnerable as they have the highest Heat Wave EALs. The data behind

Heat Wave Expected Annual Loss (EAL). Source: FEMA NRI (December 2022)



these calculations used to determine frequency of heat events is unfortunately limited to the period of time from the NCEI events database, and is drawn from similar sources. NRI's EAL methodology, however, also accounts for population and property exposed to heat and considers an estimate of historic losses. The analysis from FEMA's NRI reveals that expected annual loss (EAL) from heat waves is highest for Des Moines, Lee, Scott and Wapello counties. The EALs for these counties are between $700,000 and $800,000. Two other counties have Heat Wave EALs above $300,000: Pottawattamie at $543,520 and Woodbury at $440,128. The Heat Wave EAL for the entire state, inclusive of all counties, is $8,903,060 (as of December 2022, per the FEMA NRI at https://hazards.fema.gov/nri/map).

Excessive heat can impose stress on humans and animals. Heatstroke, sunstroke, cramps, exhaustion, and fatigue are possible with prolonged exposure and/or physical activity due to the body's inability to dissipate the heat. Urban areas are particularly at risk because of air stagnation and large quantities of heat-absorbing materials such as streets and buildings. This is known as the urban heat island (UHI) effect, and the EPA states that it causes urban areas to be warmer than outlying areas by 1-7˚F during the day, and 2-5˚F overnight.[68] There is also variation within urban areas, depending on tree cover and green spaces. Evapotranspiration from plants, can lower temperatures by 2-9˚F in peak summer heat.[69]

Urban areas can experience higher heat index ratings due to the urban heat island effect, but rural areas are also vulnerable to heat, especially as much of the agricultural labor performed in rural areas is outdoors. In 41 counties in Iowa, over ten percent of the population works in industries that are often outdoors or not air-conditioned (excluding manufacturing).[70] In ten of these counties, over ten percent of the population are farmers.[71]

Beyond human vulnerability to heat, Iowa is also at risk of losses in transportation, agriculture, energy, and other sectors. Extreme heat can also result in distortion and failure of structures and surfaces such as roadways and railroad tracks. Increased energy demand during excessive heat events can lead to brownouts or blackouts. Engines and machinery, including vehicles, may be susceptible to high heat as well. Certain herbicides are more likely in high heat to vaporize without necessarily dissipating, consequently killing local trees and other plants, including non-immune crops.

Without proper planning and mitigation, livestock and crops are both vulnerable to heat, exposing Iowa's agriculture to losses and reduced productivity. The following map shows crop loss claims due to heat and hot wind, as recorded by the USDA's Risk Management Agency.

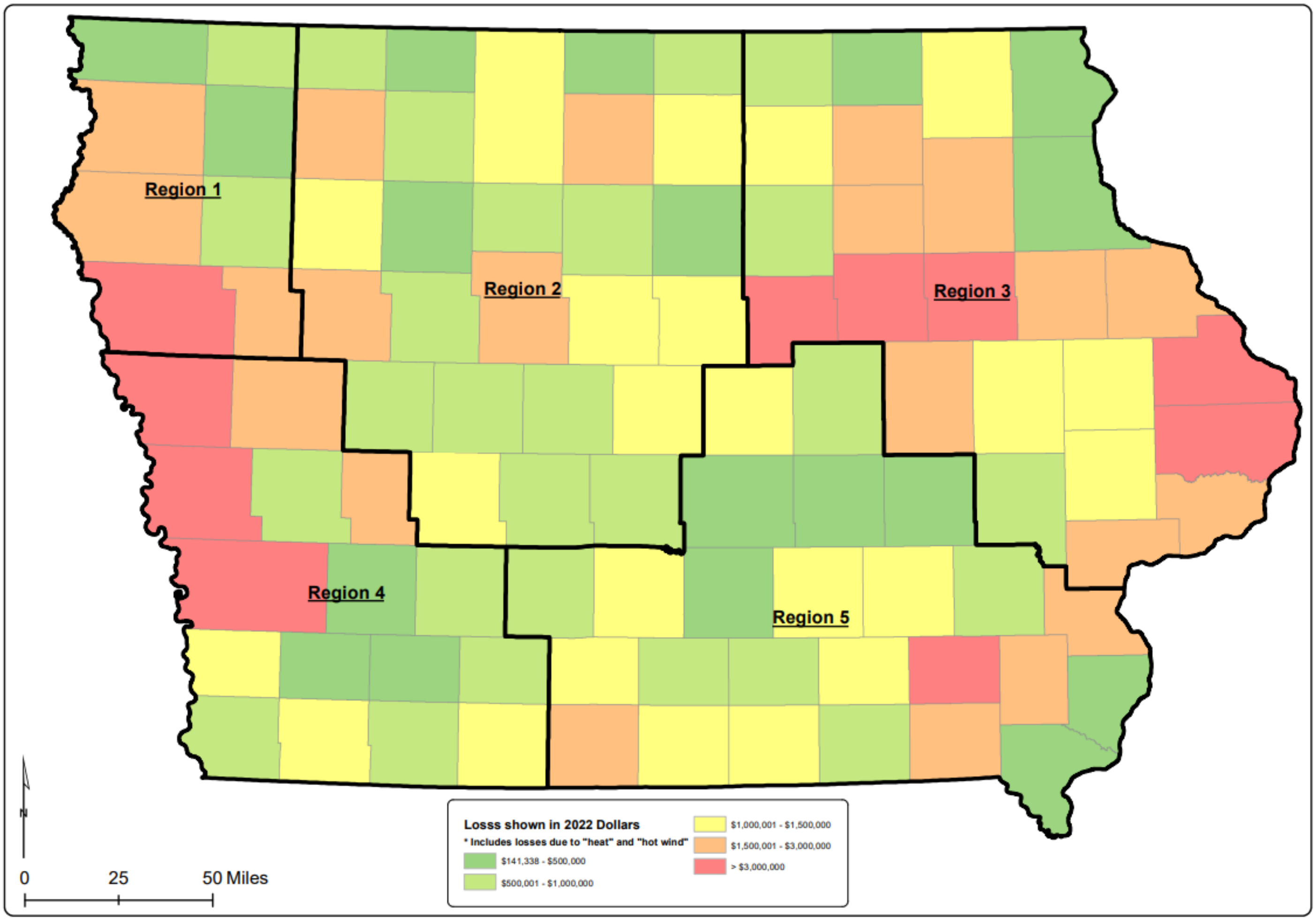
[68] EPA, Heat Island Effect (2022), Retrieved from https://www.epa.gov/heatislands

[69] EPA, Using Trees and Vegetation to Reduce Heat Islands (2022), retrieved from https://www.epa.gov/heatislands/using-trees-and-vegetation-reduce-heat-islands, citing Kurn, D., S. Bretz, B. Huang, and H. Akbari. 1994. The Potential for Reducing Urban Air Temperatures and Energy Consumption through Vegetative Cooling (PDF) (31 pp, 1.76MB). ACEEE Summer Study on Energy Efficiency in Buildings, American Council for an Energy Efficient Economy. Pacific Grove, California.

[70] This figure combines data from the U.S. Bureau of Economic Analysis (number of farmers per county), the U.S. Bureau of Labor Statistics (number of employees per industry per county) and from the U.S. Census Bureau's American Community Survey (2021) (population).

[71] This figure combines data from the U.S. Bureau of Economic Analysis (number of farmers per county) and from the U.S. Census Bureau's American Community Survey (2021) (population).

Inflation-Adjusted Crop Insurance Claims due to Heat (1989-2022)



Extreme heat can affect everyone to some degree, but certain characteristics make populations more vulnerable than others. An analysis of the deaths caused by heat waves in Chicago and Paris identified two key risk factors positively associated with death: age and social isolation.[72] Young children and older adults are especially vulnerable. The US EPA states that, "generally those who are older, very young, or poor, or have physical challenges or mental impairments, are at elevated risk".[73] Specifically, populations over 65, infants under 1 year, the homeless, the poor, people who are socially isolated, people with mobility restrictions or mental impairments, people taking certain medications, people engaged in vigorous outdoor exercise or work, or those under the influence of drugs or alcohol. FEMA also cites studies saying that "Living alone, being confined to bed, using

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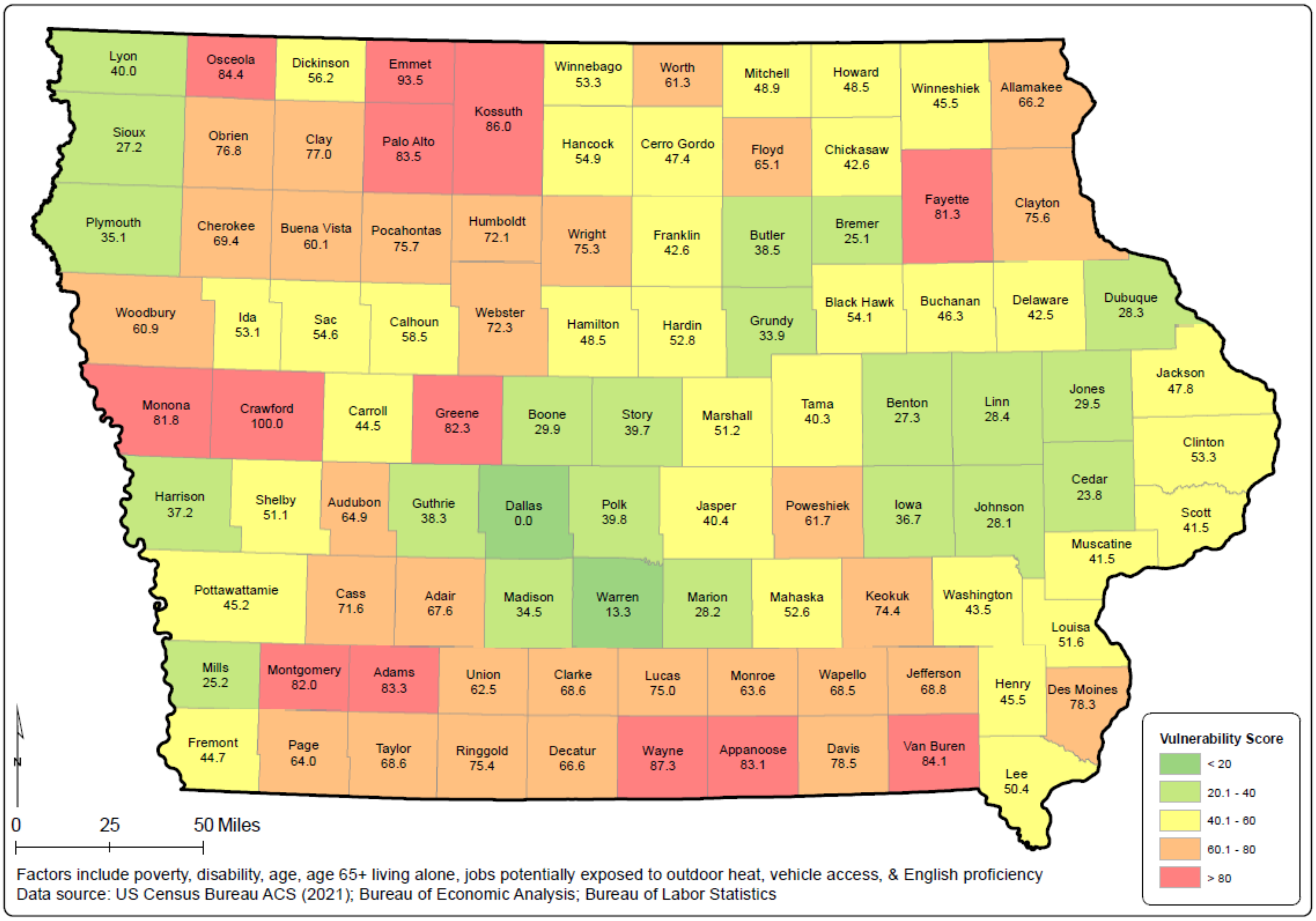
[72] Kafeety, A., Henderson, S.B., Lubik, A. *et al.* Social connection as a public health adaptation to extreme heat events. *Can J Public Health* **111**, 876–879 (2020). https://doi.org/10.17269/s41997-020-00309-2, *citing* Klinenberg, E. (2002). *Heat wave: a social autopsy of disaster in Chicago* (1st ed.). Chicago: The University of Chicago Press; *also citing* Poumadère, M., Mays, C., Le Mer, S., & Blong, R. (2005). The 2003 heat wave in France: dangerous climate change here and now. *Risk Analysis*, *25*(6), 1483–1494. https://doi.org/10.1111/j.1539-6924.2005.00694.x.

[73] U.S. EPA, Excessive Heat Events Guidebook (2016), at 5.

tranquilizers, having a mental illness, not leaving home daily, living on higher floors of multistory buildings, and being alcoholic were associated with increased risk of heat-related mortality."[74] Considering these factors,[75] these counties are considered the most vulnerable for this hazard:

Adams	Appanoose	Crawford	Emmet	Fayette
Greene	Kossuth	Monona	Montgomery	Osceola
Palo Alto	Van Buren	Wayne		

Social Vulnerability to Heat



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[74] Rupa Basu and Jonathan M. Samet, "Relation Between Elevated Ambient Temperature and Mortality: A Review of the Epidemiologic Evidence," Epidemiologic Reviews 24, no. 2 (2002), 190. *Retrieved from* https://community.fema.gov/ProtectiveActions/s/article/Extreme-Heat-Impact

[75] This analysis uses data from the US Census Bureau's American Community Survey (2021 5-year estimates for poverty, limited English proficiency, children under age 15, adults over 65, population with a disability, population without access to a vehicle, and adults over 65 living alone), the Bureau of Economic Analysis (number of farmers), and the Bureau of Labor Statistics (number of employees in potentially heat vulnerable industries).

E. Identification of Possible Actions to Mitigate Problem

Urban environments are especially heat-prone, but as part of the built environment, it is also modifiable. The urban heat island effect can be mitigated by increasing tree canopy, increasing shade during hot months, installing air conditioning where lacking, reducing heat-absorbing material like concrete and asphalt where possible (e.g. replacing concrete surfaces with grass or plantings, or grey infrastructure with green infrastructure generally),

The U.S. EPA offers the following actions as widely accepted mitigation actions that would provide relief and minimize health impacts from excessive heat events:

- "Establishing and facilitating access to air-conditioned public shelters
- Ensuring real-time public access to information on the risks of the EHE conditions and appropriate responses through broadcast media, web sites, toll-free phone lines, and other means
- Establishing systems to alert public health officials about high-risk individuals or those in distress during an EHE (e.g., phone hotlines, high-risk lists)
- Directly assessing and, if needed, intervening on behalf of those at greatest risk (e.g., the homeless, older people, those with known medical conditions)."[76]

Suggested state action:

- Implement heat safety policies for employees working outdoors or in working environments with risk factors for heat illness (see, e.g., Johnson County's Heat Illness Prevention Plan).

Suggested local actions[77]:

1) Establish buddy systems to check on isolated individuals during severe weather events (see, e.g., New York City's "Be a Buddy" program or Philadelphia's block captain system)
2) Improve messaging for older adults on the dangers of extreme heat, especially prior to and during heat events. Include advice on ways to reduce risk and places to go during heat events.
3) Equip public facilities, community centers and resilience hubs to act as cooling centers during extreme heat events, especially those frequented by older adults and children, such as libraries.
4) Institute rental code provisions requiring indoor cooling to prevent heat-related illnesses and deaths. These reflect stipulations for minimum heating in rentals in winter months that already exist in many jurisdictions. When possible, provide resources to help renters and landlords upgrade existing facilities with cooling equipment that does not exacerbate heat in the future.
5) Publicize information related to the health effects of heat events, including specific heat events, to improve compliance with recommended actions
6) Suspend utility shutoffs during excessive heat events
7) Develop and promote actions to reduce effects of urban heat islands (reducing concrete/asphalt surfaces, increasing tree canopy, etc.)

[76] U.S. EPA, Excessive Heat Events Guidebook (2016), at 6.
[77] See U.S. EPA, Excessive Heat Events Guidebook (2016) for more information on potential mitigation actions.

3.3.7. Dam/Levee Failure

A. General Description

Dam/levee failure is the uncontrolled release of water resulting from a structural failure in a dam, wall, dike, berm, or area of elevated soil that causes flooding. Possible causes of the breach could include flooding, earthquakes, blockages, landslides, lack of maintenance, improper operation, poor construction, vandalism, terrorism, erosion, piping, saturation, or under seepage.

*1. **Dams***

Dams are constructed for a variety of purposes, including flood control, erosion control, water supply impoundment, hydroelectric power generation, and recreation. In Iowa, dams are classified according to the downstream damage that would occur if they were to fail. The more risk, the higher the standards that must be met when that dam is constructed or modified. There are three dam classifications: high hazard, moderate (aka "significant") hazard, and low hazard. These classifications do not describe the current condition of the dam. High hazard dams have to meet the State's highest level of criteria and are inspected on a two-year cycle. The classification may change over time because of development downstream from the dam since it was constructed. Older dams may not have been built to the standards of its new classification. Below are the hazard classifications defined by the Iowa Department of Natural Resources (DNR):

- **High Hazard** – A dam is classified as high hazard when it is located in an area where dam failure may create a serious threat of loss of human life.
- **Moderate (Significant) Hazard** – A dam is classified as moderate hazard when failure may damage isolated homes or cabins, industrial or commercial buildings, moderately-traveled roads, or interrupt major utility services. A moderate hazard dam does not present a substantial risk of loss of human life. A dam is also classified as moderate hazard when the dam and its impoundment are themselves of public importance, such as a dam that is associated with public water supply systems, industrial water supply or public recreation, or is an integral feature of a private development complex.
- **Low Hazard** – A dam is classified as low hazard when damage from a failure would be limited to loss of the dam, livestock, farm outbuildings, agricultural lands and lesser-used roads, and where loss of human life is considered unlikely.

Dam hazard potential classifications have nothing to do with the condition of a dam, only the potential for death and/or destruction due to the size of the dam, the size of the impoundment, and/or the characteristics of the area downstream of the dam. The DNR tracks all dams in Iowa with a height of at least 25 feet or a total storage of at least 50 acre-feet of water. The inventory excludes all dams less than a height of six feet regardless of storage capacity and dams less than 15 acre-feet of storage regardless of height.

Approximately 4000 dams are on the State of Iowa Dam Inventory. Of these, only "major" dams are subject to periodic inspections. Major dams are all high hazard dams as well as significant hazard dams that have a permanent storage volume exceeding 100 acre-feet or a total water storage volume to the top of the dam exceeding 250 acre-feet. Low hazard dams are considered major dams if the product of storage (acre-feet) x height (feet) exceeds 30,000 acre-feet. The height and storage volumes are measured at the emergency spillway crest unless there is not an emergency spillway in which case they are measured at the top of the dam. Federally-owned dams are not subject to State inspection.

2. ***Levees***

We've all heard a chain is only as strong as its weakest link. A levee is similar, except that a little vole cannot dig a destructive hole in a long chain, but it can in a miles-long levee, or non-levee embankment. Besides the threats posed by animals, levees are subject to other threats that can undermine their effectiveness. Levees constructed of compacted clay with a high plasticity tend to crack during cycles of long dry spells. During heavy rainfalls that follow the dry spells, water fills the cracks and fissures. This increases hydrostatic forces, and the water also is slowly absorbed by the clay causing an increase in the unit weight of the clay as well as a decrease in its shear strength. This results in a simultaneous increase of the slide (driving) forces and a decrease of the resisting (shear strength) forces. Furthermore, in levee failure, the cyclic shrink/swell behavior of the cracked clay zone results in a progressive reduction of the shear strength of the clay, perhaps approaching its residual strength. It also results in the deepening of the cracked clay zone; cracks may reach a depth of 9 feet (2.74 m) or more, especially for clays with a plasticity index greater than 40. The end result may be a sloughing failure following a heavy rainfall.

Proper design and construction can limit the probability of a levee failure. Development in the watershed can raise flood levels and make a levee designed and constructed under previous characteristics inadequate for current runoff conditions. Also, as stated in the recent *Iowa Statewide Levee Districts Study*, levees "change over time: banks erode, closures rust, animals burrow, and pumps wear out. Ongoing vigilance is needed to ensure that levee infrastructure will perform properly during a flood event." [78]

When someone talks about a "levee", it could have several different meanings. Some people may refer to a "Corps" levee, or an accredited levee, or a certified levee. There are specific definitions for certified levee and accredited levee, but "Corps" levee could mean different things. When people use that term, they could be referencing a certified levee, an accredited levee, a levee owned and operated by the US Army Corps of Engineers (USACE), or a levee that receives (and passes) regular inspections under the Levee Safety Program and remains eligible for the PL 84-99 Rehabilitation Program (described in more detail below). People also often use the term "levee" to refer to an embankment which in no way is tied to or inspected by USACE or any other qualified professional. To distinguish such structures from levees, that do receive inspections and sustained maintenance, these embankments are sometimes called "non-levee embankments".

Non-levee embankments could easily lead to a false sense of security as those behind the embankment may believe they are adequately protected from many flood events, but the non-levee embankment could have some very "weak links" that no one knows about because the levee has not been inspected recently, or no one has clear authority and responsibility to maintain it even if an inspection is done and corrective items are identified. Levees/embankments are only resilient if there is a sustainable system in place to maintain each linear foot of the levee year-in/year-out, week-in/week-out for as long as it is expected to protect what is behind the levee/embankment.

There are multiple sources of information on the levees and non-levee embankments found in Iowa. Data sources include the U.S. Army Corps of Engineers (USACE) National Levee Database (NLD), the Iowa Department of Natural Resources (DNR), and officials of levee districts and local jurisdictions.

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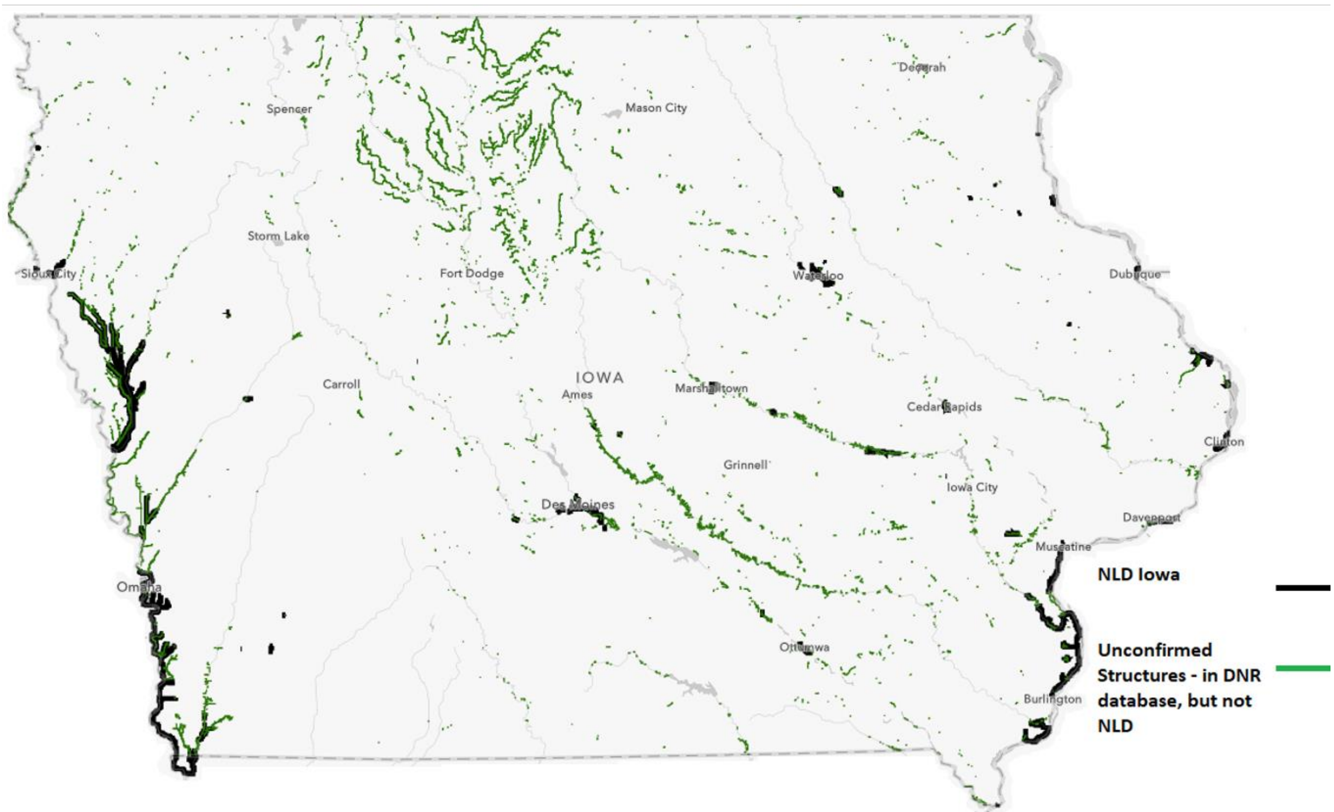
[78] Page 10. The *Iowa Statewide Levee Districts Study* was commissioned by the Iowa Legislature in the 2022 Session. The *Study* was completed and published December 2022.

Authorized in 2007, the NLD houses information for all levees related to USACE authorities, including levees that were built by USACE and have a local sponsor and ones that are part of the USACE Rehabilitation Program. The NLD includes information about the location, general condition, and risks associated with different levee systems. Data from levees owned and operated by other agencies, municipalities, and levee districts is added as it becomes available. The intent is that levee-related information for all levees will eventually be included, allowing for a comprehensive understanding of the benefits and risks associated with levees. However, we are certainly not at that point yet. As the adjoining map shows, many embankments are in the state that are not found in the NLD database.



In addition to the levees documented in the NLD, the map above shows non-levee embankments mapped by the DNR found through examination of LiDAR (light detection and radar) maps. These LiDAR maps, showing elevation differences throughout the state, were examined to identify structures that appeared as though they might function as levees – that is, they appeared they might contain, control or divert the flow of temporary flood waters. The map shows structures in green that have an elevation change of three feet or more. This method and standard for identifying potential levees is often too sensitive and many, perhaps even most, are abandoned levees or water containment features. Even if one of these unconfirmed structures is currently functioning as a levee, it is not known how well-built it is and what level of protection it provides. Some were designed and built to hold back floods with an annual chance of occurrence of less than 0.2 percent- in other words, they should hold back the 500-

year flood. Other embankments shown, however, were constructed with no design at all and it is anyone's guess what level of flood they may hold back. Some embankments on the map were designed and constructed with materials meant to withstand specific loads and pressures, while others may have been constructed with whatever material was handy and the load they could withstand is completely unknown. Some embankments may receive inspections and are properly maintained, while with others everyone has forgotten they are even there.

The NLD is available to anyone with an internet connection. But, what one may find on the NLD may not be up-to-date. For instance, recent interviews (conducted in 2022) with county and levee officials revealed that levees labeled as "active" on the NLD had in fact been abandoned for several years. Levee sponsors also disputed some of the features identified on the NLD as either not being present, or present in different quantities. However, though there are some discrepancies with the NLD information, it remains the gold standard for levee information within the federal government.

As of June 2022, the NLD reports 182 levee systems in Iowa containing 750 miles of levees. The NLD provides information on the associated risks and condition of some 80 levee systems associated with USACE programs (about 450 miles of levees). It has location information on another 100 or so non-USACE levee systems (approximately 190 miles), but little to no information about the condition and risk associated with such systems. It has been estimated there may be over 890 miles of levees in Iowa, leaving perhaps 16 percent of levees in the state undocumented and not participating in any sort of maintenance or inspection plan.

"Accredited" Levee Systems

An accredited levee system is a system that FEMA has determined to meet the design, data, and documentation requirements of 44 Code of Federal Regulations (CFR) 65.10; it therefore can be shown on a Flood Insurance Rate Map (FIRM) as reducing the base flood hazard. This determination is based on documentation, submitted on behalf of a community and certified by a professional engineer, that shows compliance with 44 CFR 65.10. The area landward of an accredited levee system is shown on the FIRM as a moderate-hazard area, labeled Zone X (shaded), except for areas of interior drainage flooding such as ponding areas, which will be shown as high-hazard areas, called Special Flood Hazard Areas (SFHAs). Flood insurance is not mandatory in Zone X (shaded) areas, but it is mandatory in SFHAs. FEMA strongly encourages flood insurance for all structures in floodplains and especially in areas landward of levees.

A "provisionally accredited levee" (PAL) designation may be used for a levee system that FEMA has previously accredited as providing base flood hazard reduction on an effective FIRM, and for which FEMA is awaiting data and/or documentation that will show the levee system is compliant with 44 CFR 65.10. Before FEMA will apply the PAL designation to a levee system, the community or levee owner needs to sign and return an agreement indicating that the data and documentation required for compliance with 44 CFR 65.10 will be provided within a specified timeframe. Where PAL requirements are met, the impacted area landward of a PAL system on the updated FIRM is shown as a moderate-hazard area, labeled Zone X (shaded and PAL note is added). Therefore, flood insurance is not mandatory for insurable structures in the area landward of a levee system with a PAL designation; however, flood insurance and other protective FEMA accreditation measures are strongly encouraged by FEMA. A community is eligible to receive a PAL designation for a levee system only once. As of June 2022, 60 of Iowa's levee systems in the NLD have been accredited by FEMA with an additional 15 systems having a PAL designation.

Levee certification

FEMA accredits levees on its maps that have been certified by others. They do not certify nor decertify levees. They will de-accredit (remove) levees from its maps that are not certified (and thus cause properties behind the levee to end up in the 1% flood hazard area). Levee certification must be accomplished by a professional engineer or a Federal agency with levee design and construction qualifications. FEMA neither certifies nor decertifies levees. And, they do not fund certification of levees. USACE is not funded to certify levees other than those it owns and operates. They may perform certifications (evaluations) upon request of a non-Federal levee sponsor on a reimbursable basis. USACE levee certification requirements are consistent with FEMA's 44 CFR 65.10. USACE will not issue a partial certification; they evaluate the entire system. (So, if a portion of the system does not meet requirements, the whole system will not be certified, even if the one inadequate portion is owned and sponsored by a different entity than the rest of the system that is compliant.) USACE certification has a maximum period of validity of 10 years.

USACE Levee Inspections[79]

USACE regularly inspects levees within its Levee Safety Program[80] to monitor their overall condition, identify deficiencies, verify that needed maintenance is taking place, determine eligibility for federal rehabilitation assistance (in accordance with P.L. 84-99), and provide information about the levees on which the public relies. Inspection information also contributes to risk assessments and, as described above, supports levee accreditation decisions. Both Routine Inspections (annual) and Periodic Inspections (every 5 years) result in a final inspection rating for operation and maintenance. The rating is based on the levee inspection checklist, which includes 125 specific items dealing with operation and maintenance. The rating designations are:

(1) Acceptable

(2) Minimally Acceptable

(3) Unacceptable

Each levee segment receives an overall segment inspection rating of Acceptable, Minimally Acceptable, or Unacceptable. If a levee system comprises one or more levee segments (if there are different levee sponsors for different parts of the levee) then the overall levee system rating is the lowest of the segment ratings.

PL 84-99 Levee Rehabilitation Program

Levees that meet specific criteria are eligible through the PL 84-99 Rehabilitation Program for federally-funded levee repairs after a flood event. USACE determines if a levee is eligible for the PL 84-99 Rehabilitation Program using a subset of the items evaluated during a Levee Safety Program inspection. These items must receive Acceptable or Minimally Acceptable ratings for the levee to remain eligible for the PL 84-99 Rehabilitation Program. After storm damage, the cost share for repairs for levees in the Rehabilitation Program is 80 percent federal/20 percent non-federal for non-federal Flood Control Works (FCW), and it is 100% federal for federally-constructed FCW.

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[79] This information is from https://www.usace.army.mil/Missions/Civil-Works/Levee-Safety-Program/Levee-Inspections/.
[80] For more information see https://www.usace.army.mil/Missions/Civil-Works/Levee-Safety-Program/.

B. Previous Occurrences

The most significant historical occurrences of dam failure in Iowa were in 1968 and 2010. In 1968 the Virden Creek Dam in Waterloo failed, claiming one life. In July of 2010 a 92-year-old dam at Lake Delhi was breached at a nine-mile-long lake that was owned by a local homeowner's recreation association. The breach occurred at a 300-foot section of the earthen portion of the dam near the main concrete structure. The Lake Delhi breach caused significant property loss, an evacuation of as many as 700 residents near the dam, as well as severe economic impacts to the tourism industry in the area.

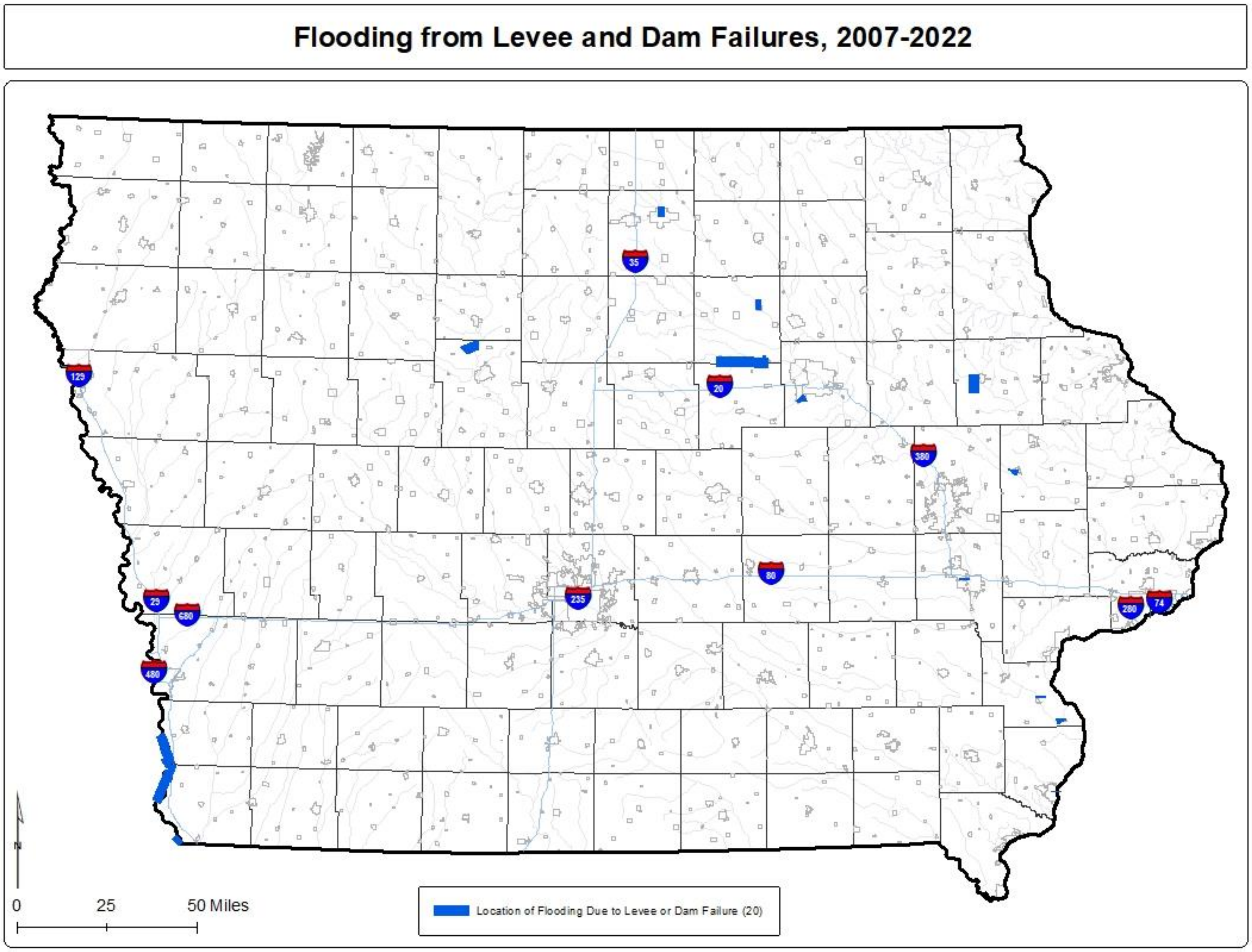
Although not a dam failure, there was concern during the very wet period in 1993 that water would overtop the dam at Saylorville Reservoir in Polk County. With the outfall flowing at full capacity and water flowing out of the spillway, the reservoir did not overtop the dam. In addition, the flooding caused on the Missouri River by the controlled release of water from Gavins Point Dam in South Dakota in 2011 and 2019 illustrated how Iowa could be affected by a dam failure that occurred outside of the state borders.

Other previous dam incidents include the uncontrolled releases of the Maquoketa Milldam in 1927, the Humboldt Milldam in 1969, the Seymour Reservoir Dam in 1976, and the Fertile Mill Dam in 1979.

As for levees, the limits of many levees were tested and sometimes exceeded due to historic flooding in the state in 1993 and again in 2008. Of the 275 U.S. Army Corps of Engineers (USACE) levees affected by the 1993 flood, 85 percent held. Of the 15 percent that failed, 31 overtopped (11 percent), eight eroded and ruptured (3 percent), and three breached (1 percent). The performance of nonfederal levees was much worse: only 43 percent withstood the trauma, and 800 of 1,400 failed. The rate of failure of a levee or floodwall is difficult to predict, with sudden failure a possibility. Another major event occurred in 2011 when a levee along the Missouri River failed, threatening the City of Hamburg, Interstate 29, rural residences, county roads, and crops. That year, flow in the Missouri River topped 216,000 cubic feet per second (cfs) at a point where the previous record had been 120,000 cfs (in 1960). In 2011 the flow exceeded 120,000 cfs for 84 straight days.

The year 2019 brought more major disaster events due to levee failures along the Missouri River. One of the hardest hit areas was the town of Pacific Junction. The entire town was flooded by Missouri River water. US Highway 34 in Mills County sustained extreme damage. U.S. Interstate 29 along the Missouri River was inundated and partially destroyed, as was the Interstate 680 bypass around Council Bluffs and the Omaha metropolitan area. Bartlett and Thurman were evacuated due to the levee breaks.

The following map shows where previous dam and levee failures occurred in the years 2007 through 2022. The chart following provides details about those events (data retrieved from the NCEI Storm Events Database).



Year	Month	County	PROPERTY Damage	Crop Damage	Episode Description
2007	May	HARRISON	$15,000,000	$0	Rainfall of 5 inches fell across the Missouri Valley May 5th causing the levee along Willow Creek to fail. The levee failure caused substantial flooding with many residents barely able to escape the rising flood waters. At least 77 homes and 6 businesses were flooded and declared an almost complete loss. Many vehicles were also flooded or severely damaged. Interstate 29, Highway 30 and other roads were closed for a while. The high water continued well into the following week. Road repair alone was estimated to cost several million dollars. Although homes in higher sections escaped flood waters from the levee break, many sustained damage due to flooded basements, mudslides or basement walls caving in. The flooding prompted schools to close.
2007	August	WEBSTER	$10,000	$0	Heavy rains fell on already saturated ground over northern Iowa. Flooding occurred in Ft. Dodge when a levee was reportedly breached on the Des Moines River at the hydroelectric plant.

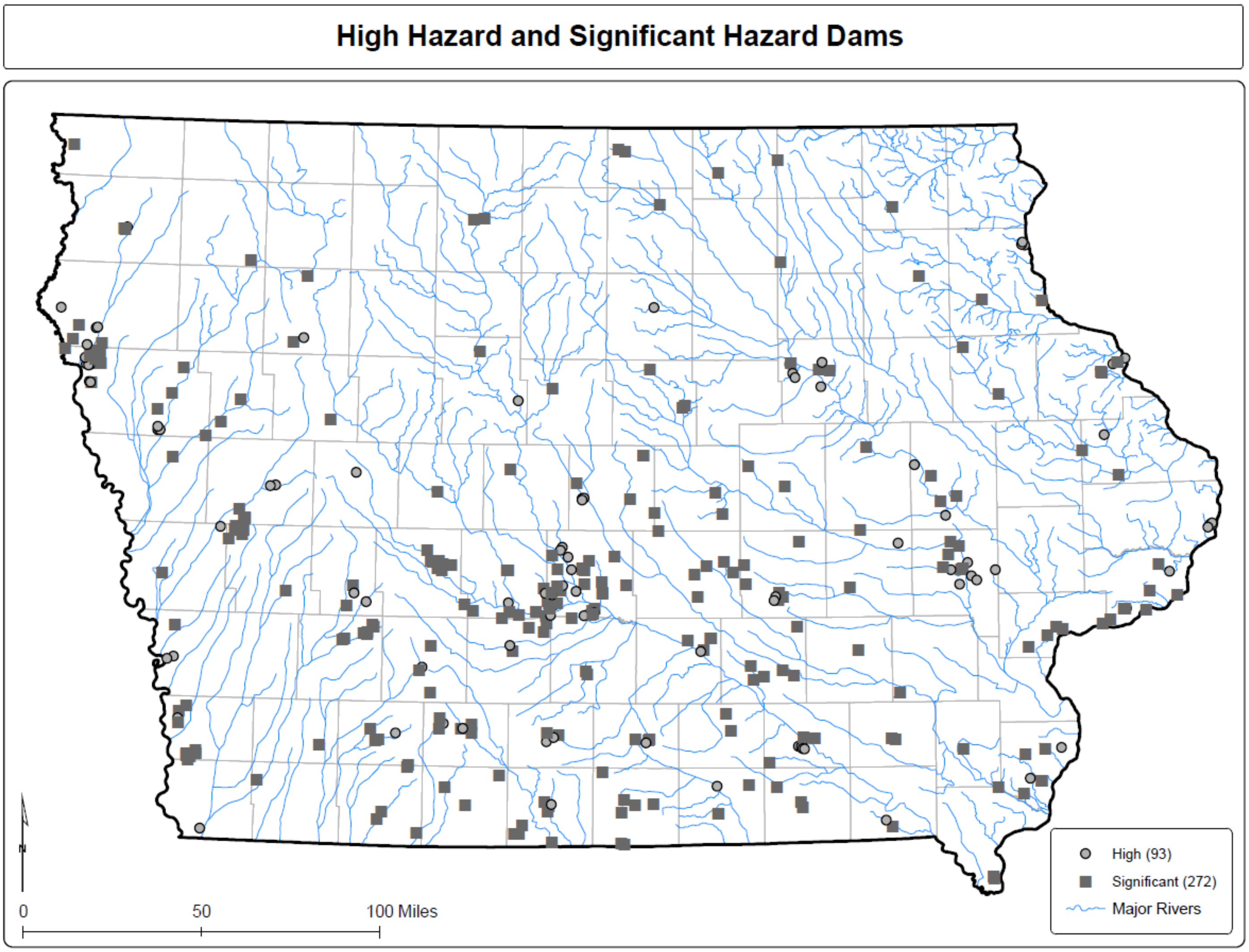
Year	Month	County	PROPERTY Damage	Crop Damage	Episode Description
2008	June	BUTLER	$100,000	$0	Heavy rainfall of 3 to 6 inches occurred in a broad swath extending from west central into north central, and parts of central and northeast Iowa. Eventually, the rain lead to major flooding along many rivers. The situation was very serious over the north central and northeast counties. A levy was breached in the Mason City area as the Winnebago River rose to 3 feet over the record stage. The city was inundated by water. The water treatment plant was under water and non-operational, all power was lost in the city. The river cut a new channel and changed course into the downtown area. In the New Hartford area, a dam broke on Beaver Creek, resulting in the water level rising 2 feet above the all-time record level. High water along the mainstem Cedar River also caused communities to lose water. Nashua lost water as the water plant became flooded. Flooding along the Shell Rock River resulted in water supply loss in the town of Rockford.
2008	June	CERRO GORDO	$500,000	$0	
2008	June	JONES	$500,000	$0	Major to record flooding on the Iowa and Wapsipinicon Rivers caused levees to fail at Coralville, IA and Anamosa, IA on June 12. A levee failed along the Wapsipinicon River on the southwest side of Anamosa, IA below the County Rd E34 bridge around 9:16 pm June 12. Flash flooding resulted on the southwest side of Anamosa, IA. The Crandic Railroad embankment along the Iowa River in Coralville, IA failed around 9:01 pm June 12. Flash flooding resulted in sections of Coralville, IA along 1st Avenue and Highway 6.
2008	June	JOHNSON	$500,000	$0	
2008	June	LOUISA	$100,000	$0	Flood waters from the Iowa River caused a levee to fail near the intersection of I Avenue and County Road G62 just east northeast of Wapello, IA. This levee failure resulted in flash flooding of approximately 500 acres which included four homes located behind the levee.
2008	June	LOUISA	$0	$0	Major to record flooding on the Iowa River caused a levee to fail near Oakville, Iowa in Louisa County on June 14, 2008. An indirect fatality occurred when a 35-year old man drowned in the flood waters in rural Oakville while attempting to swim to his house to gather belongings.
2008	June	POLK	$7,000,000	$0	High water in the Des Moines River stressed the levee system in Des Moines. The crest had passed, but water levels were still within a foot of the record crest. A weak spot in the levee in the Birdland Park area gave way in spite of heroic efforts of citizens and National Guard members to shore the levee up. A breech of about 100 feet wide occurred causing an area to flood, with waters rising 4 feet in about an hour, and 8 feet in several hours. About 271 homes, a High School and several businesses were affected by the flooding. Damage to a fertilizer and chemical business was around $3,000,000, while $1,100,000 damage was done to North High School.
2010	July	DELAWARE	$25,000,000	$0	Heavy rain caused record flooding on the Maquoketa River which resulted in the failure of a berm on the south side of the Lake Delhi/Hartwick Lake dam on July 24. The dam failure resulted in flooding of residences along the Maquoketa River immediately downstream of the dam. In addition, the dam failure emptied out the 9 mile stretch of the Maquoketa River that constituted Lake Delhi/Hartwick Lake.

Year	Month	County	PROPERTY Damage	Crop Damage	Episode Description
2011	June	FREMONT	$100,000	$0	A federal levee southwest of Hamburg failed causing the Missouri River to flash flood across several farmsteads in the area and eventually across a highway and Interstate 29 then toward the Hamburg area.
2013	May	BLACK HAWK	$200,000	$0	A warm front moved into Iowa from the 28th into the 29th. Surface temperatures warmed into the low 80s and thunderstorms developed, producing heavy rainfall, high winds and hail. Several storms produced 60 to 70 MPH winds, downing numerous trees and power lines. Rainfall of 2 to 4 inches was observed from southwest through central into northeast Iowa. This caused flash flooding. In the Hudson and Dunkerton areas of Black Hawk County, flooding in town occurred as the levy partially failed on the river.
2013	May	BUTLER	$250,000	$0	A series of thunderstorms moved southeast across the state, producing heavy rain. Highway closings were numerous with many small creeks overflowing their banks and causing flash flooding. Terrace Ave, a gravel road levee, began to fail and water flowed into New Hartford.
2016	Sept.	BUTLER	$300,000	$0	The Emergency Manager reported a levee on the west side of Clarksville along the Shell Rock river failed and the southwest side of town flooded. Residents evacuated.
2019	March	FREMONT	$14,000,000	$7 million	A bomb cyclone moved out of the Rockies March 13 and helped create flooding across eastern Nebraska and western Iowa. Four to fifteen inches of snow cover remained across the Missouri River valley. The ground was frozen with frost depths of 15 to 23 inches. Warm temperatures rapidly melted snow and 1 to 2.5 inches of rain fell in 48 hours. Due to the frozen ground and 1 to 2 feet of thick ice in rivers, widespread flooding occurred. Flooding due to expansive levee breaches devastated many communities. Nearly 50 levees breached on the Platte, Elkhorn and Missouri Rivers. U.S. Interstate 29 along the Missouri River was inundated and partially destroyed, as was the Interstate 680 bypass around Council Bluffs-Omaha metropolitan area. Two levee breeches resulted in flash flooding from the Missouri River. One of the hardest hit areas was the town of Pacific Junction. The entire town was flooded by Missouri River water. US Highway 34 in Mills County sustained extreme damage. Bartlett and Thurman were evacuated due to the levee breaks.
2019	March				
2019	March	MILLS			
2019	March				
2019	April	SCOTT	$0	$0	A temporary flood barrier protecting downtown Davenport failed April 30th. Flood water from the Mississippi River quickly spread over several blocks of downtown Davenport, including the lower floors of many businesses, flooding vehicles in the area, and trapping some people in buildings requiring them the be removed by boat. No injuries or fatalities occurred.
2019	June	DES MOINES	$0	$0	Several clusters of strong storms moved over southeast Iowa, northeast Missouri, and west central Illinois June 1st. The temporary flood barrier system in downtown Burlington failed, flooding the Port of Burlington Welcome Center, the Memorial Auditorium, and affecting several other businesses with water from the Mississippi River which was over major flood stage.

C. Location, Probability and Intensity

1. Dams

Iowa DNR's Dam Inventory lists 93 high hazard[81] dams statewide with an additional 272 significant hazard dams. The locations of these dams are shown on the map below. Woodbury County has the most high hazard dams (11), followed by Polk County (10). Woodbury and Polk counties also have the largest numbers of significant hazard dams, with Woodbury having 21 and Polk 16.



Iowa can be, and in fact has been, impacted by dams outside the state. Most notable is the Gavins Point Dam on the Missouri River about 70 miles upriver from Sioux City, Iowa. As mentioned in sub-section B above, historic releases from the Gavins Point Dam flooding caused flooding along the Missouri River in 2011 and again in 2019 in the counties of Woodbury, Monona, Harrison, Pottawattamie, Mills and Fremont. Though the probability is not great, a release from a failure of Gavins Point Dam would impact these counties even more so than the flooding

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[81] The National Inventory of Dams (NID) lists 95, but some of those have duplicate NID identification numbers.

from either 2011 or 2019 (both of which resulted through a controlled release at the dam). Impacts from the controlled releases in those years resulted in hundreds of millions of dollars of damage and included closed bridges and roads, and flooded homes, businesses and farm fields.

Precipitation extremes and increased frequency of precipitation that lead to flooding may put stress on dam structures for a variety of reasons. More extreme precipitation events could increase the frequency of intentional discharges. Many other climate-related impacts, including shifts in seasonal and geographic rainfall patterns, could also cause the flow behavior of rivers to deviate from previous hydrographs. When flows are greater than expected, spillway overflow events (often referred to as design failures) can occur. These overflows result in increased discharges downstream and increased flooding potential. Although climate change will not increase the probability of catastrophic dam failure, it may increase the probability of design failure.

The above map shows the locations of dams whose failures could cause disaster. It does not indicate which locations are more probable to fail, nor does it show which locations would have the greatest intensity of flood waters following a failure. Dams that are in poorer condition are generally considered to be more probable to fail than dams in satisfactory condition. The following chart shows the conditions of dams, determined at last inspection, along with their location and other identifying information. Those rated in "Poor" condition are listed first, followed by those rated in Fair condition. Within in each rank of condition (Poor, Fair, or Satisfactory), the dams are then listed by the normal storage amount (in acre-feet), which serves as a measure of the anticipated intensity of the amount of water that would or could wash downstream.

The dams that are owned and operated by the US Army Corps of Engineers are listed at the end of the chart. These dams are not subject to state regulation. They are inspected, however, and the dates of their last inspections are noted in the chart. As they are not regulated by the State of Iowa, they do not receive a condition rating by the state.

Note that the purpose of this chart is to illustrate probability and intensity (i.e. extent) of dams in the state; it does not indicate what, or how much, is at risk below each dam. A separate chart shows such vulnerabilities in sub-section D.

Dam Name	NIDID	County	City	Normal Storage (Acre-Ft)	Last Inspection Date	Condition Assessment
Middle Pond Dam	IA01699	Iowa	MIDDLE AMANA	78	5/23/2023	Poor
Held Watershed Site E-3	IA01857	Plymouth	HINTON	47	8/9/2022	Poor
Smokey Hollow Subwatershed Site 4	IA02310	Woodbury	SMITHLAND	34	10/18/2022	Poor
Schoenewe Dam	IA02080	Des Moines	BURLINGTON	28	9/12/2022	Poor
Red Haw Dam	IA01357	Lucas	LAKE ELLIS	1,040	6/15/2023	Rated Fair
Beeds Lake Dam	IA01344	Franklin	HAMPTON	870	6/23/2022	Rated Fair
Bacon Creek Watershed Site A-2-4	IA01791	Woodbury	SIOUX CITY	385	8/10/2022	Rated Fair
Fort Des Moines Park Dam	IA01840	Polk	DES MOINES	120	3/12/2021	Rated Fair
Coralville Regional Detention Basin	IA03397	Johnson	CORALVILLE	83	6/21/2022	Rated Fair

Dam Name	NIDID	County	City	Normal Storage (Acre-Ft)	Last Inspection Date	Condition Assessment
Held Watershed Site E-4	IA01856	Plymouth	HINTON	65	8/9/2022	Rated Fair
Focht & Schindel Dam	IA00860	Plymouth	SIOUX CITY	42	6/19/2023	Rated Fair
Bacon Creek Watershed Site A-1-1	IA01796	Woodbury	SIOUX CITY	40	8/10/2022	Rated Fair
Prescott Flood Prevention Dam	IA01459	Adams	PRESCOTT	27	8/30/2021	Rated Fair
Meyer Dam	IA01926	Crawford	DENISON	17	10/11/2022	Rated Fair
Slaughter Flood Control Dam	IA02063	Clayton	MC GREGOR	13	5/5/2023	Rated Fair
Smokey Hollow Subwatershed Site 2	IA02312	Woodbury	SMITHLAND	10	10/18/2022	Rated Fair
Clinton Flood Control - May Pond Dam	IA02328	Clinton	CLINTON	?	10/3/2022	Rated Fair
Viking Road Detention Dam	IA03104	Black Hawk	CEDAR FALLS	?	9/27/2021	Rated Fair
Brushy Creek Dam	IA03116	Webster	FRASER	19,660	5/30/2023	Satisfactory
Little River Watershed Site M-1	IA02263	Decatur	STATE OF MISSOURI	10,869	5/23/2023	Satisfactory
Twelve Mile Creek Watershed Site M-1	IA02194	Union	AFTON	10,200	8/3/2021	Satisfactory
Lake Sugema Dam	IA02626	Van Buren	FARMINGTON	7,350	7/3/2023	Satisfactory
Pleasant Creek Lake Dam	IA02083	Linn	PALO	7,100	10/24/2022	Satisfactory
Lost Grove Lake	IA04083	Scott	Mississippi River	6,080	10/14/2022	Satisfactory
Maffitt Reservoir Dam	IA01338	Dallas	WEST DES MOINES	5,200	5/31/2023	Satisfactory
Lake Ponderosa Dam	IA00972	Poweshiek	SPRING VALLEY	2,500	10/21/2022	Satisfactory
Arbor Valley Lake Dam	IA03905	Clarke	OSCEOLA	1,592	5/9/2022	Satisfactory
Pony Creek Watershed Site 21	IA00675	Mills	PACIFIC JUNCTION	1,122	7/5/2023	Satisfactory
Leisure Lake Dam	IA00522	Jackson	FULTON	670	9/27/2022	Satisfactory
Deer Creek Dam	IA02937	Plymouth	SIOUX CITY	665	6/19/2023	Satisfactory
Lake of the Hills Dam	IA00978	Scott	DAVENPORT	613	9/17/2021	Satisfactory
Greenfield Reservoir Dam	IA02267	Adair	GREENFIELD	612	5/24/2021	Satisfactory
Littlefield Lake Dam	IA01691	Audubon	ATLANTIC	561	6/4/2021	Satisfactory
Yellowsmoke Park Dam	IA02014	Crawford	DENISON	497	4/24/2023	Satisfactory

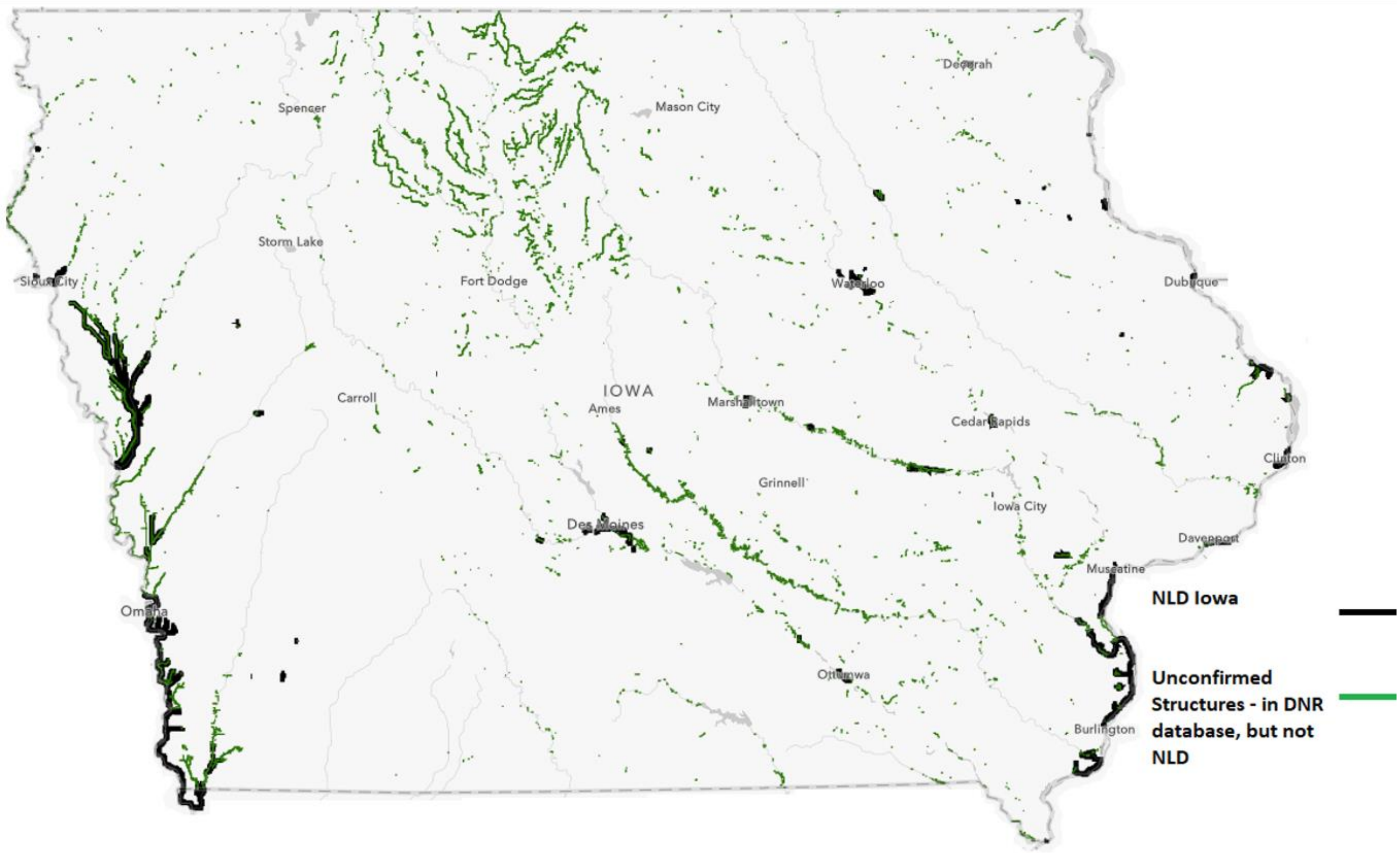
Dam Name	NIDID	County	City	Normal Storage (Acre-Ft)	Last Inspection Date	Condition Assessment
Indian Creek Watershed Site 2	IA01664	Pottawattamie	COUNCIL BLUFFS	341	9/7/2021	Satisfactory
Clive Lake Dam	IA02456	Polk	CLIVE	274	4/11/2023	Satisfactory
Lake Cimarron	IA04140	Poweshiek	Lake Ponderosa	264	8/23/2022	Satisfactory
Virden Creek Dam	IA01972	Black Hawk	WATERLOO	249	9/27/2021	Satisfactory
Hamburg Watershed Site M-1	IA00392	Fremont	HAMBURG	220	7/5/2023	Satisfactory
Grade Lake Dam	IA01819	Clarke	OSCEOLA	217	5/23/2023	Satisfactory
Storm Lake - Northeast Dredge Spoil Disposal Dam	IA03546	Buena Vista	Storm Lake	195	6/13/2022	Satisfactory
Zaiser Dam	IA04148	Des Moines	Kingston (not incorporated)	135	9/12/2022	Satisfactory
Bacon Creek Watershed Site A-3	IA01797	Woodbury	SIOUX CITY	126	8/10/2022	Satisfactory
Twenty-Sixth Street Stormwater Detention Basin	IA03540	Polk	Des Moines	97	8/15/2022	Satisfactory
Bamboo Ridge Lake	IA04139	Black Hawk	Waterloo	94	8/31/2022	Satisfactory
Aegon Dam	IA03081	Linn	CEDAR RAPIDS	88	5/23/2023	Satisfactory
West Lakes Office Park Dam	IA02499	Polk	WEST DES MOINES	85	4/11/2023	Satisfactory
Davids Creek Watershed Site 1B-2	IA01470	Audubon	EXIRA	84	6/11/2021	Satisfactory
Creston Flood Prevention Dam	IA01756	Union	CRESTON	72	7/26/2021	Satisfactory
Mill Picayune Watershed Site B-3	IA00467	Harrison	DUNLAP	70	6/20/2023	Satisfactory
Bacon Creek Watershed Site A-3-1	IA01795	Woodbury	SIOUX CITY	70	8/10/2022	Satisfactory
Southfork Dam	IA02411	Dallas	CLIVE	67	4/11/2023	Satisfactory
Heritage Woods Dam	IA03548	Dallas	Van Meter	61	8/19/2022	Satisfactory
Jefferson Park Watershed Site 3	IA01104	Wapello	OTTUMWA	59	6/27/2023	Satisfactory
Smokey Hollow Subwatershed Site 1	IA02311	Woodbury	SMITHLAND	59	10/18/2022	Satisfactory
South Ridge Estates - East Dam	IA03533	Sioux	Sioux Center	46	6/19/2023	Satisfactory
Oaknoll Dam	IA02848	Johnson	IOWA CITY	43	6/21/2022	Satisfactory
Bacon Creek Watershed Site C-1	IA01685	Woodbury	SIOUX CITY	40	8/10/2022	Satisfactory
Jefferson Park Watershed Site 10	IA02314	Wapello	OTTUMWA	40	6/27/2023	Satisfactory

Dam Name	NIDID	County	City	Normal Storage (Acre-Ft)	Last Inspection Date	Condition Assessment
Jefferson Park Watershed Site 5	IA02348	Wapello	OTTUMWA	38	6/27/2023	Satisfactory
Scott Blvd Dam	IA02117	Johnson	IOWA CITY	34	6/22/2022	Satisfactory
Glen Ellen Subwatershed Site 3-2	IA01253	Woodbury	LUTON	32	8/10/2022	Satisfactory
Covered Bridge Estates Dam	IA03516	Madison	Carlisle	31	5/30/2023	Satisfactory
Easter Lake Stormwater Retention Basin - Site 9	IA03519	Polk	Des Moines	23	8/3/2022	Satisfactory
Monument Road Dam	IA04081	Pottawattamie	Missouri River	22	9/7/2021	Satisfactory
Siegel Flood Control Dam	IA02062	Clayton	MC GREGOR	21	5/5/2023	Satisfactory
Glen Oaks Country Club Dam	IA04280	Polk	West Des Moines	20	11/1/2021	Satisfactory
Pikes Peak Flood Control Dam	IA02061	Clayton	MC GREGOR	19	5/5/2023	Satisfactory
Carroll Stormwater Detention Dam	IA02352	Carroll	CARROLL	19	5/17/2023	Satisfactory
Jefferson Park Watershed Site 4	IA01105	Wapello	OTTUMWA	18	6/27/2023	Satisfactory
Smokey Hollow Subwatershed Site 3	IA02313	Woodbury	SMITHLAND	18	10/18/2022	Satisfactory
Fieldstone Addition Dam	IA03436	Black Hawk	Cedar Falls	16	8/31/2022	Satisfactory
Parkview Lake Dam	IA02030	Polk	URBANDALE	15	6/8/2023	Satisfactory
Jefferson Park Watershed Site 1	IA01103	Wapello	OTTUMWA	14	6/27/2023	Satisfactory
Glen Ellen Subwatershed Site 3-1	IA01254	Woodbury	BRONSON	14	8/11/2022	Satisfactory
North Branch Ralston Creek Dam	IA02249	Johnson	IOWA CITY	?	6/22/2022	Satisfactory
Clinton Flood Control - First Congregational Church Dam	IA02329	Clinton	CLINTON	?	10/3/2022	Satisfactory
Ames Basin #2	IA02392	Story	AMES	?	10/26/2022	Satisfactory
Ames Basin #3	IA02393	Story	AMES	?	10/26/2022	Satisfactory
Ames Basin #4	IA02394	Story	AMES	?	10/26/2022	Satisfactory
Clinton Flood Control - Whittier Dam	IA02826	Clinton	CLINTON	?	10/3/2022	Satisfactory
Clinton Flood Control - Springvalley Pond Dam	IA02827	Clinton	CLINTON	?	10/3/2022	Satisfactory
Carter Road Stormwater Detention Dam	IA03512	Dubuque	Dubuque	?	9/17/2021	Satisfactory

Dam Name	NIDID	County	City	Normal Storage (Acre-Ft)	Last Inspection Date	Condition Assessment
SW Branch Dry Run Creek Stormwater Detention Dam	IA03547	Black Hawk	Cedar Falls	?	9/27/2021	Satisfactory
West Branch Flood Control Dam	IA04223	Johnson	West Branch	?	9/21/2021	Satisfactory
Rathbun Reservoir Dam	IA00016	Appanoose	RATHBUN	205,359	3/15/2021	USACE Inspected 2021
RED ROCK RESERVOIR DAM	IA00013	Marion	CARLISLE	189,000	4/18/2022	USACE Inspected 2022
Saylorville Reservoir Dam	IA00017	Polk	DES MOINES	74,000	12/6/2022	USACE Inspected 2022
Coralville Dam	IA00012	Johnson	IOWA CITY	28,100	8/6/2019	USACE Inspected 2019
Big Creek Diversion Dam	IA00014	Polk	POLK CITY	7,600	12/6/2022	USACE Inspected 2022
Big Creek Barrier Dam	IA00018	Polk	POLK CITY	100	12/6/2022	USACE Inspected 2022

2. *Levees*

The map below shows levees discovered from different sources. One source of the data is the National Levee Database (NLD). The NLD includes 715 miles of levees in Iowa, composed of 180 levee systems and 1855 levee structures. Not all levees in the database are USACE levees. In fact, of the 180 levee systems, nearly half (86) are non-USACE levee systems (comprising 146 miles). But, the USACE has verified the location and size of all the levees in the NLD and has estimated the areas protected by these levees. The levees in Iowa in the NLD protect approximately 159,000 structures at a value of about $57.9 billon. The population in these levee-protected areas is about 432,000. The NLD indicated that 383.39 miles of levees were accredited.



The NLD also reports the ratings given for many levees at their last periodic inspections. For Iowa, the NLD reveals that:

- 275.37 miles of levees had an inspection rating of "Unacceptable"
- 279.97 miles of levees had an inspection rating of "Minimally Acceptable"
- 14.4 miles of levees had an inspection rating of "Acceptable"

For the 2022 *Iowa Statewide Levee Districts Study*, a review of recent USACE inspection reports of NLD levees was conducted and "found that of the 89 systems inspected, only five systems obtained an acceptable rating with another 49 systems were identified as minimally acceptable, and 35 were found to be unacceptable."[82]

The following table lists the levees found on the NLD that protect at least one building or person. The chart is presented to illustrate locations where probability of levee failure may be more likely, as well as where there would be areas of greater extent (measured in square miles) if a levee fails. Levees with inspections ratings of Unacceptable are generally considered more likely to fail than those rated as Acceptable. Those with "Unacceptable" inspection ratings are listed first in the chart. Within the Unacceptable category, the levees that protect the most area are listed first.

Not all levees have recent inspection ratings. Of those that do, far more have an Unacceptable than do an Acceptable rating. If the same proportion of levees without inspection ratings are Unacceptable as the ones that

[82] *Iowa Statewide Levee Districts Study*, December 2022. Page 22

are rated, than the levees without inspections would be more likely to be Unacceptable and thus more likely to fail. In the chart below, the levees without inspection ratings are listed after those with an Unacceptable rating. They are then secondarily ranked by how much area the levee protects. Following the list of levees without inspection ratings, the levees rated as Minimally Acceptable are listed and then those that are rated Acceptable.

COUNTIES	LOCATION	Miles of Levee	Leveed Area in Square Miles	System ID	NAME	Inspection Rating	Inspection Date	IS USACE ?	Segment Count
Fremont (IA) Atchison(MO), Nemaha (NE)	Fremont Co., Iowa	41.77	109.76	47050 00030	L-575 (BW-McKissock-Buchanan-Atchison-Hamburg)	Unacceptable	4/24/2017	Yes	6
Fremont, Mills	Bartlett, Mills Co.	14.50	22.30	47050 00031	L-594-601	Unacceptable	7/18/2017	Yes	5
Harrison, Monona	Blencoe, Monona Co.	23.86	19.51	47050 00017	Little Sioux RB & Monona-Harrison LB - Intercounty	Unacceptable	5/31/2017	Yes	2
Monona, Woodbury	Rodney, Monona Co.	22.40	15.91	47050 00008	Little Sioux & Wolf Creek	Unacceptable	7/26/2017	Yes	4
Fremont	Thurman, Fremont Co.	12.76	15.91	47050 00029	L-594-575 (BW-PV-Waubonsie)	Unacceptable	4/12/2017	Yes	4
Pottawattamie	Council Bluffs, Pottawattamie Co.	14.87	15.09	47050 00037	L-627 MO River LB & Indian Creek RB	Unacceptable	5/18/2021	Yes	1
Monona	Hornick, Monona Co.	16.23	14.86	47050 00005	Little Sioux Wolf Cr RB & W Fork LB - Intercounty	Unacceptable	6/2/2017	Yes	3
Monona	Hornick, Woodbury Co.	3.62	14.14	47050 00006	Little Sioux West Fork Ditch RB - Intercounty	Unacceptable	5/31/2017	Yes	3
Pottawattamie	Council Bluffs, Pottawattamie Co.	8.86	7.46	47050 00036	L-624 MoRiv LB & Indian LB & Mosquito Creek RB	Unacceptable	8/27/2017	Yes	1
Black Hawk	Waterloo, Black Hawk Co.	9.56	6.42	51059 20003	WATERLOO & EVANSDALE, IA - LDB CEDAR RIVER	Unacceptable	5/5/2010	Yes	3
Pottawattamie	Council Bluffs, Pottawattamie Co.	7.39	4.71	47050 00034	L-624-627-611-614 - Mosquito Cr & Upper Pony Cr	Unacceptable	9/27/2016	Yes	4
Monona	Turin, Monona Co.	10.35	4.68	47050 00004	Little Sioux LB & Maple River RB - Intercounty	Unacceptable	4/6/2021	Yes	1
Mills	Pacific Junction, Mills Co.	3.26	4.33	47050 00032	L-601 - Watkins Ditch RB - Watkins DD	Unacceptable	7/18/2017	Yes	2
Monona	Castana, Monona Co.	5.77	3.99	47050 00002	Little Sioux LB - Nagel DD South	Unacceptable	7/25/2017	Yes	1
Monona	Turin, Monona Co.	8.07	3.85	47050 00012	Little Sioux LB & Beaver Creek RB - Intercounty	Unacceptable	4/6/2021	Yes	1

COUNTIES	LOCATION	Miles of Levee	Leveed Area in Square Miles	System ID	NAME	Inspection Rating	Inspection Date	IS USACE ?	Segment Count
Monona, Woodbury	Rodney, Monona Co.	5.77	3.27	4705000003	Little Sioux LB - Nagel DD North	Unacceptable	7/25/2017	Yes	1
Monona	Turin, Monona Co.	4.07	2.00	4705000007	Little Sioux LB - Nagel and Intercounty DD	Unacceptable	6/1/2017	Yes	2
Woodbury	Sioux City, Woodbury Co.	5.32	1.94	4705000026	Sioux City - Floyd River RB	Unacceptable	9/20/2017	Yes	1
Black Hawk	Waterloo, Black Hawk Co.	5.26	1.76	5105920002	WATERLOO, IA - RDB CEDAR RIVER / RDB BLACK HAWK CK. (SOUTH WEST)	Unacceptable	5/16/2012	Yes	2
Woodbury	Sioux City, Woodbury Co.	3.84	1.68	4705000025	Sioux City - Floyd River LB	Unacceptable	9/21/2017	Yes	1
Black Hawk	Waterloo, Black Hawk Co.	4.49	1.27	5105920001	WATERLOO, IA - RDB CEDAR RIVER / LDB BLACK HAWK CK. (NORTH WEST)	Unacceptable	5/15/2012	Yes	1
Pottawattamie	Council Bluffs, Pottawattamie Co.	2.29	0.92	4705000035	L-611-614 - Upper Pony Creek LB&Lat 1B RB	Unacceptable	9/28/2016	Yes	2
Woodbury	Sioux City, Woodbury Co.	1.37	0.65	4705000028	Sioux City - Big Sioux River LB	Unacceptable	7/24/2019	Yes	1
Woodbury	Sioux City, Woodbury Co.	1.01	0.46	4705000168	Sioux City - Perry Creek Right Bank	Unacceptable	9/7/2021	Yes	1
Winneshiek	Decorah, Winneshiek Co.	2.03	0.40	5705000044	Dry Run - Decorah - Right Bank	Unacceptable	11/10/09	Yes	1
Sioux	Hawarden, Sioux Co.	1.16	0.39	4705000022	Hawarden-Dry Creek LB	Unacceptable	9/9/2021	Yes	1
Sioux	Hawarden, Sioux Co.	1.09	0.37	4705000021	Hawarden - Dry Creek RB	Unacceptable	9/9/2021	Yes	1
Ida	Ida Grove, Ida Co.	0.81	0.31	4705000018	Ida Grove - Odebolt Creek RB & Maple LB	Unacceptable	5/11/2021	Yes	1
Black Hawk	Waterloo, Black Hawk Co.	1.06	0.08	5105920004	WATERLOO, IA – Wastewater Treatment Plan (SOUTH)	Unacceptable	5/5/2010	Yes	1
Clayton	Elkport, Clayton Co.	0.53	0.06	5105590001	Elkport, IA	Unacceptable	12/24/16	Yes	3
Muscatine	Muscatine, Muscatine Co.	0.19	0.05	5105230002	MUSCATINE, IA - GENEVA CREEK (NORTH)	Unacceptable	11/8/2016	Yes	1
Mills	Emerson, Mills Co.	0.02	0.04	4705000024	Emerson - Indian Creek RB	Unacceptable	5/3/2021	Yes	1
Woodbury	Sioux City, Woodbury Co.	0.25	0.02	4705000167	Sioux City - Perry Creek Left Bank	Unacceptable	9/7/2021	Yes	1
Harrison	Missouri Valley, Harrison Co.	7.14	12.77	1705700444	MISSOURI VALLEY LEVEE 2	No Recent Inspection Record		No	1

COUNTIES	LOCATION	Miles of Levee	Leveed Area in Square Miles	System ID	NAME	Inspection Rating	Inspection Date	IS USACE ?	Segment Count
Pottawattamie	Council Bluffs, Pottawattamie Co.	3.94	12.23	1705700407	ALLEN CREEK LEVEE 2	No Recent Inspection Record		No	1
Mills	Pacific Junction, Mills Co.	7.02	9.10	1705000630	MILLS COUNTY AG LEVEES	No Recent Inspection Record		No	1
Jackson	Jackson Co.	17.90	6.89	5105590300	GREEN ISLAND LEVEE & DRAINAGE DISTRICT NO. 1	No Recent Inspection Record		No	1
Monona	Whiting, Monona Co.	5.05	6.15	1705700459	LITTLE SIOUX - INTERCOUNTRY DD	No Recent Inspection Record		No	1
Harrison, Pottawattamie	Loveland, Pottawattamie Co.	7.33	5.79	240005000005	Missouri Valley Levee 3	No Recent Inspection Record		No	1
Muscatine	Nichols, Muscatine Co.	3.71	5.00	1705700464	HOCKEY'S SLOUGH LEVEE A	No Recent Inspection Record		No	1
Harrison	Missouri Valley, Harrison Co.	11.43	4.30	1705000444	Missouri Valley Levee 1	No Recent Inspection Record		No	1
Monona	Whiting, Monona Co.	2.10	3.72	1705000459	UNDEFINED	No Recent Inspection Record		No	1
Pottawattamie	Loveland, Pottawattamie Co.	2.27	2.98	1705000407	ALLEN CREEK LEVEE	No Recent Inspection Record		No	1
Iowa	West Amana Co.	5.93	2.77	1705000408	AMANA	No Recent Inspection Record		No	1
Harrison	Missouri Valley, Harrison Co.	4.65	2.50	240005000006	Missouri Valley Levee 4	No Recent Inspection Record		No	1
Harrison	Missouri Valley, Harrison Co.	4.89	2.28	240005000007	Missouri Valley Levee 5	No Recent Inspection Record		No	1
Mills	Bartlett, Mills Co.	0.67	2.07	1705800291	MRLS L-601 WATKINS-LD B	No Recent Inspection Record		No	1
Polk	Carlisle, Polk Co.	3.22	1.92	1705000383	Polk County Drainage District Number 9	No Recent Inspection Record		No	1
Monona	Whiting, Monona Co.	2.93	1.52	1705000461	UNDEFINED	No Recent Inspection Record		No	1
Linn	Cedar Rapids, Linn Co.	1.06	1.11	5105950083	Cedar Rapids, IA - East	No Recent Inspection Record		Yes	1
Mills	Bartlett, Mills Co.	0.66	1.02	1705700291	MRLS L-601 WATKINS-LD A	No Recent Inspection Record		No	1

COUNTIES	LOCATION	Miles of Levee	Leveed Area in Square Miles	System ID	NAME	Inspection Rating	Inspection Date	IS USACE ?	Segment Count
Fremont	Sidney, Fremont Co.	1.12	0.99	1705000451	WINSLOW SEGMENT 1	No Recent Inspection Record		No	1
Muscatine	Nichols, Muscatine Co.	1.84	0.92	1705100464	HOCKEY'S SLOUGH LEVEE	No Recent Inspection Record		No	1
Harrison	Logan, Harrison Co.	3.26	0.92	240005000012	Missouri Valley Levee 10	No Recent Inspection Record		No	1
Wapello	Ottumwa, Wapello Co.	3.20	0.77	5105940005	OTTUMWA, IA - LDB DES MOINES R (NORTH)	No Recent Inspection Record		No	1
Harrison	Missouri Valley, Harrison Co.	2.79	0.75	240005000010	Missouri Valley Levee 8	No Recent Inspection Record		No	1
Muscatine	Nichols, Muscatine Co.	1.93	0.68	1705200464	HOCKEY'S SLOUGH LEVEE B	No Recent Inspection Record		No	1
Des Moines	Des Moines Co.	2.45	0.63	1705700226	DES MOINES COUNTY DRAINAGE DISTRICT SEVEN 4	No Recent Inspection Record		No	1
Jackson	Jackson Co.	2.44	0.58	1705000621	GREEN ISLAND 1	No Recent Inspection Record		No	1
Des Moines	Des Moines Co.	1.66	0.56	1705900226	DES MOINES COUNTY DRAINAGE DISTRICT SEVEN 1	No Recent Inspection Record		No	1
Black Hawk	Waterloo, Black Hawk Co.	0.66	0.54	1705100168	WATERLOO FLOOD CONTROL PROJECT LEVEE 2	No Recent Inspection Record		No	2
Linn	Cedar Rapids, Linn Co.	1.45	0.51	1705000456	CEDAR RIVER LEVEE NO. 3	No Recent Inspection Record		No	1
Des Moines	Des Moines Co.	0.46	0.51	1705000384	DES MOINES COUNTY DRAINAGE DISTRICT SEVEN 3	No Recent Inspection Record		No	1
Des Moines	Oakville, Des Moines Co.	2.72	0.48	1705200225	HAWKEYE-DOLBY 2	No Recent Inspection Record		No	1
Fremont	Riverton, Fremont Co.	1.14	0.45	1705100451	WINSLOW SEGMENT 2	No Recent Inspection Record		No	1
Scott	Riverdale, Scott Co.	1.78	0.44	1705000211	ALCOA LEVEE	No Recent Inspection Record		No	2
Scott	Rock Island Arsenal, Rock Island Co., Illinois	4.29	0.37	1705000214	BETTENDORF LOCAL FPP	No Recent Inspection Record		No	1
Harrison	Logan, Harrison Co.	1.33	0.30	240005000011	Missouri Valley Levee 9	No Recent Inspection Record		No	1

COUNTIES	LOCATION	Miles of Levee	Leveed Area in Square Miles	System ID	NAME	Inspection Rating	Inspection Date	IS USACE ?	Segment Count
Story	Maxwell, Story Co.	0.63	0.30	1705000466	INDIAN CREEK LEVEE - STORY CO, IA	No Recent Inspection Record		No	1
Harrison	Logan, Harrison Co.	1.12	0.29	240005000008	Missouri Valley Levee 6	No Recent Inspection Record		No	1
Wapello	Ottumwa, Wapello Co.	0.79	0.28	240005000004	Old Joe Griffin Levee	No Recent Inspection Record		No	1
Jackson	Sabula, Jackson Co.	1.41	0.27	1705000228	SABULA	No Recent Inspection Record		No	1
Pottawattamie	Council Bluffs, Pottawattamie Co.	0.51	0.27	1705100205	MOSQUITO CREEK TIEBACK	No Recent Inspection Record		No	1
Montgomery	Elliott, Montgomery Co.	0.72	0.22	1705000462	COE CREEK LEVEE	No Recent Inspection Record		No	1
Crawford	Denison, Crawford Co.	1.83	0.20	1705000495	SEWAGE DISPOSAL POND LEVEE 1	No Recent Inspection Record		No	1
Harrison	Missouri Valley, Harrison Co.	1.18	0.19	240005000013	Missouri Valley Levee 11	No Recent Inspection Record		No	1
Pottawattamie	Council Bluffs, Pottawattamie Co.	0.68	0.18	1705200205	COUNCIL BLUFFS LEVEES	No Recent Inspection Record		No	1
Dallas	Van Meter, Dallas Co.	1.78	0.18	1705000477	VAN METER LEVEE	No Recent Inspection Record		No	1
Des Moines	Burlington, Des Moines Co.	0.25	0.15	1705000394	BURLINGTON NORTHERN BOTTOMS LEVEE	No Recent Inspection Record		No	1
Winneshiek	Decorah, Winneshiek Co.	0.45	0.12	1705000396	COLLEGE LEVEE	No Recent Inspection Record		No	1
Linn	Cedar Rapids, Linn Co.	0.44	0.12	1705000455	CEDAR RIVER LEVEE NO. 1	No Recent Inspection Record		No	1
Story	Cambridge, Story Co.	1.27	0.10	1705000465	BALLARD CREEK LEVEE	No Recent Inspection Record		No	1
Des Moines	Oakville, Des Moines Co.	1.01	0.09	1705100225	HAWKEYE-DOLBY 1	No Recent Inspection Record		No	1
Polk	Des Moines, Polk Co.	0.79	0.09	1705000232	WDM-I	No Recent Inspection Record		No	1
Des Moines	Des Moines Co.	0.18	0.07	1705200384	DES MOINES COUNTY DRAINAGE DISTRICT SEVEN 7	No Recent Inspection Record		No	1

COUNTIES	LOCATION	Miles of Levee	Leveed Area in Square Miles	System ID	NAME	Inspection Rating	Inspection Date	IS USACE ?	Segment Count
Clayton	Volga, Clayton Co.	0.71	0.06	5105910002	Volga, IA - Nagle Creek	No Recent Inspection Record		No	1
Black Hawk	Waterloo, Black Hawk Co.		0.05	1705000168	WATERLOO FLOOD CONTROL PROJECT LEVEE 1	No Recent Inspection Record		No	2
Des Moines	Oakville, Des Moines Co.	0.48	0.04	1705300225	HAWKEYE-DOLBY 3	No Recent Inspection Record		No	1
Clinton	Clinton, Clinton Co.	0.20	0.04	5105050002	Clinton, IA LDB Turtle Creek	No Recent Inspection Record		No	1
Winneshiek	Decorah, Winneshiek Co.	0.47	0.03	1705000404	VALLEY VIEW DRIVE LEVEE	No Recent Inspection Record		No	1
Johnson	Tiffin, Johnson Co.	0.46	0.03	1705000454	CLEAR CREEK PARK STREET LEVEE	No Recent Inspection Record		No	1
Ida	Ida Grove, Ida Co.	0.31	0.01	1705000453	BADGER CREEK LEVEE	No Recent Inspection Record		No	1
Clayton	Marquette, Clayton Co.	0.97	0.01	1705000447	MISSISSIPPI RIVER LEVEE - MARQUETTE	No Recent Inspection Record		No	1
Winneshiek	Decorah, Winneshiek Co.	0.27	0.01	1705000392	LEVEE #1 HIGHWAY 9	No Recent Inspection Record		No	1
Marshall	Marshalltown, Marshall Co.	0.15	0.01	1705000628	IOWA RIVER PRIVATE - MARSHALLTOWN	No Recent Inspection Record		No	1
Dubuque	Cascade, Dubuque Co.	0.09	0.00	1705000406	CASCADE	No Recent Inspection Record		No	1
Black Hawk	Waterloo, Black Hawk Co.			5105920005	WATERLOO, IA - VIRDEN CREEK DRY RESERVIOR	No Recent Inspection Record		Yes	1
Harrison, Monona	Whiting, Monona Co.	10.60	111.16	4705000015	Little Sioux West Fork Ditch RB & Monona-Harrison Ditch RB - Intercounty	Minimally Acceptable	7/12/2016	Yes	4
Louisa, Muscatine	Fruitland, Louisa Co.	28.41	45.97	5105220001	MUSCATINE ISLAND L&DD, MUSCATINE - LOUISA CO DD NO 13 & MUSCATINE, IA	Minimally Acceptable	3/26/2015	Yes	3
Mills, Pottawattamie	Mills Co.	21.12	36.97	4705000033	L-611-614-MoRiv LB & Upr Pony Creek LB & L1B LB	Minimally Acceptable	9/21/2015	Yes	2
Des Moines, Louisa	Oakville, Louisa Co.	46.85	35.37	5105070001	Two Rivers L&DD - Upper Unit	Minimally Acceptable	11/29/17	Yes	2
Des Moines	Des Moines Co.	29.22	31.27	5105070002	Two Rivers L&DD - Middle Unit	Minimally Acceptable	11/29/17	Yes	1

COUNTIES	LOCATION	Miles of Levee	Leveed Area in Square Miles	System ID	NAME	Inspection Rating	Inspection Date	IS USACE ?	Segment Count
Lee	Lee Co.	31.55	23.66	5105130001	Green Bay Levee & Drainage District No. 2	Minimally Acceptable	11/16/17	Yes	1
Pottawattamie, Douglas	Council Bluffs, Pottawattamie Co.	12.17	9.78	4705000082	Omaha - Missouri River RB	Minimally Acceptable	9/9/2016	Yes	1
Harrison, Monona	Little Sioux, Harrison Co.	7.37	8.80	4705000009	Little Sioux LB & Hogue Ditch LB - Intercounty	Minimally Acceptable	4/5/2021	Yes	1
Des Moines	Burlington, Des Moines Co.	10.72	4.44	5105070003	Two Rivers L&DD - Lower Unit	Minimally Acceptable	11/29/17	Yes	1
Polk	Des Moines, Polk Co.	9.70	4.02	5105550001	Des Moines, IA - DM-I & SEDM - Pleasant Hill - Lake Red Rock Remedial Works	Minimally Acceptable	12/2/2014	Yes	2
Monona	Blencoe, Monona Co.	8.53	3.54	4705000010	Little Sioux LB & Cottonwood Cr LB - Intercounty	Minimally Acceptable	4/5/2021	Yes	1
Clinton	Clinton, Clinton Co.	7.60	3.14	5105050001	Clinton, IA	Minimally Acceptable	11/28/17	Yes	3
Iowa	Marengo Co.	4.54	2.35	5105700001	Marengo, IA	Minimally Acceptable	11/18/14	Yes	2
Monona	Turin, Monona Co.	4.33	1.88	4705000011	Little Sioux LB & Beaver Creek LB - Intercounty	Minimally Acceptable	4/5/2021	Yes	1
Fremont	Hamburg, Fremont Co.	1.60	1.78	4705000160	Hamburg - Main Ditch 6 LB	Minimally Acceptable	4/24/2017	Yes	2
Wapello	Ottumwa, Wapello Co.	2.90	1.53	5105940003	OTTUMWA, IA - RDB DES MOINES R (SOUTH)	Minimally Acceptable	11/13/17	No	1
Marshall	Marshalltown, Marshall Co.	5.28	1.52	5105780001	MARSHALLTOWN, IA - RDB IOWA RIVER / LDB LINN CREEK (NORTH)	Minimally Acceptable	11/17/14	Yes	1
Polk	West Des Moines, Polk Co.	3.71	1.34	5105550006	WEST DES MOINES & DES MOINES, IA	Minimally Acceptable	11/25/14	Yes	2
Montgomery	Red Oak, Montgomery Co.	2.18	1.24	4705000023	Red Oak - East Nishnabotna LB	Minimally Acceptable	5/3/2021	Yes	2
Polk	Des Moines, Polk Co.	2.38	1.17	5105550002	DES MOINES, IA - DM II - RDB DES MOINES RIVER / LDB RACCOON RIVER	Minimally Acceptable	11/9/2017	Yes	1
Jackson	Sabula, Jackson Co.	2.02	0.96	5105250001	Sabula, IA	Minimally Acceptable	11/21/17	Yes	3
Tama	Tama, Tama Co.	2.68	0.76	5105890001	TAMA, IA	Minimally Acceptable	11/18/14	Yes	2
Clayton	Guttenberg, Clayton Co.	1.97	0.72	5705000042	Mississippi River - Guttenberg	Minimally Acceptable	11/16/09	Yes	1
Scott	Bettendorf, Scott Co.	2.53	0.70	5105020001	Bettendorf, IA	Minimally Acceptable	11/5/2020	Yes	1

COUNTIES	LOCATION	Miles of Levee	Leveed Area in Square Miles	System ID	NAME	Inspection Rating	Inspection Date	IS USACE ?	Segment Count
Polk	Des Moines, Polk Co.	2.01	0.62	5105550003	DES MOINES, IA - DM III - RDB DES MOINES RIVER / RACCOON RIVER	Minimally Acceptable	11/9/2017	Yes	3
Monona	Castana, Monona Co.	2.20	0.53	4705000014	Little Sioux LB - Castana - Intercounty	Minimally Acceptable	4/6/2021	Yes	1
Mahaska, Monroe, Wapello	Eddyville, Wapello Co.	1.96	0.49	5105950076	Eddyville, IA	Minimally Acceptable	11/1/2017	No	1
Monona	Castana, Monona Co.	2.21	0.47	4705000016	Little Sioux Maple River RB South - Intercounty	Minimally Acceptable	4/6/2021	Yes	1
Polk	Carlisle, Polk Co.	2.06	0.42	5105950071	AVON STATION, IA - RED ROCKS REMEDIAL WORKS	Minimally Acceptable	11/9/2017	Yes	1
Marshall	Marshalltown, Marshall Co.	2.28	0.41	5105780002	Marshalltown RDB Linn Creek/RDB Anson Creek (SOUTH EAST)	Minimally Acceptable	11/17/14	Yes	1
Polk	Des Moines, Polk Co.	1.37	0.33	5105550007	Des Moines, IA - LDB Des Moines River (Birdland)	Minimally Acceptable	11/9/2017	Yes	1
Polk	Des Moines, Polk Co.	1.26	0.26	5105550005	DES MOINES, IA - RR I - RDB RACCOON RIVER	Minimally Acceptable	11/9/2017	Yes	2
Crawford	Denison, Crawford Co.	1.08	0.25	4705000039	Denison - East Boyer River RB	Minimally Acceptable	5/11/2021	Yes	3
Warren	Carlisle, Warren Co.	1.29	0.23	5105950072	CARLISLE, IA - RED ROCK REMEDIAL WORKS	Minimally Acceptable	11/9/2017	Yes	2
Monona	Castana, Monona Co.	1.26	0.16	4705000013	Little Sioux Maple River RB North - Intercounty	Minimally Acceptable	4/6/2021	Yes	1
Black Hawk	Cedar Falls, Black Hawk Co.	0.71	0.15	5105520001	Cedar Falls, IA	Minimally Acceptable	10/29/14	Yes	1
Winneshiek	Decorah, Winneshiek Co.	1.03	0.14	5705000043	Dry Run - Decorah - Left Bank	Minimally Acceptable	11/10/09	Yes	1
Marshall	Marshalltown, Marshall Co.	1.09	0.11	5105780003	MARSHALLTOWN, IA - RDB LINN CREEK/LDB ANSON CREEK (SOUTH WEST)	Minimally Acceptable	11/17/14	Yes	1
Des Moines	Des Moines Co.	0.55	0.09	5105070004	Two Rivers L&DD - Yellow Springs Cr (SW)	Minimally Acceptable	11/29/17	Yes	2
Clayton	Volga, Clayton Co.	0.50	0.09	5105910001	VOLGA, IA	Minimally Acceptable	12/22/20	No	2
Wapello	Ottumwa, Wapello Co.	0.92	0.09	5105940001	Ottumwa, IA - LDB Des Moines R RDB Har. B CK LDB Dr D (Westside-Middle C.)	Minimally Acceptable	11/13/17	No	1
Ida	Ida Grove, Ida Co.	0.12	0.08	4705000162	Ida Grove - Odebolt Creek LB	Minimally Acceptable	5/11/2021	Yes	1

COUNTIES	LOCATION	Miles of Levee	Leveed Area in Square Miles	System ID	NAME	Inspection Rating	Inspection Date	IS USACE ?	Segment Count
Muscatine	Muscatine, Muscatine Co.	0.47	0.08	5105230001	MUSCATINE, IA - MAD CREEK (SOUTH)	Minimally Acceptable	11/21/17	Yes	1
Lee	Keokuk, Lee Co.	0.89	0.08	5105590250	Keokuk, IA	Minimally Acceptable	12/5/2014	No	1
Crawford	Denison, Crawford Co.	0.73	0.07	4705000038	Denison - East Boyer River LB (NF)	Minimally Acceptable	3/11/2020	No	1
Wapello	Ottumwa, Wapello Co.	0.62	0.04	5105940004	Ottumwa, IA - LDB Des Moines R RDB Drainage D (Westside - Upper Cell)	Minimally Acceptable	11/13/17	No	1
Ida	Ida Grove, Ida Co.	0.16	0.03	4705000161	Ida Grove - Maple River LB	Minimally Acceptable	5/11/2021	Yes	1
Iowa	Amana Co.	0.31	0.03	5105950070	AMANA, IA - CORALVILLE REMEDIAL WORKS	Minimally Acceptable	6/18/2014	Yes	1
Clayton	Elkader, Clayton Co.	0.26	0.03	5105590180	Elkader, IA	Minimally Acceptable	12/5/2017	No	1
Wapello	Ottumwa, Wapello Co.	0.47	0.02	5105940002	Ottumwa, IA - LDB Des Moines R LDB Harrows B CK (Westside - Lower Cell)	Minimally Acceptable	11/13/17	No	1
Scott	Davenport, Scott Co.	0.03	0.01	5105950075	Davenport, IA - Water Treatment Plant	Minimally Acceptable	11/6/2020	Yes	1
Louisa	Wapello, Louisa Co.	7.88	5.86	5105590190	LOUISA COUNTY LEVEE DISTRICT NO. 11	Acceptable	11/18/2016	No	2
Dubuque	Dubuque, Dubuque Co.	4.33	1.85	5105090001	Dubuque, IA	Acceptable	10/31/2017	Yes	1
Des Moines	Burlington, Des Moines Co.	3.12	0.38	5105030001	Burlington, IA (North Bottoms Levee and Drainage District)	Acceptable	11/8/2017	Yes	1
Polk	Des Moines, Polk Co.	1.10	0.27	5105550008	Des Moines, IA - RDB Des Moines River (Central Place)	Acceptable	11/9/2017	Yes	1
Dubuque, Jones	Cascade, Dubuque Co.	0.82	0.17	5105590200	Cascade, IA	Acceptable	11/3/2017	No	1

Due to the current lack of information of levees or non-levee embankments not on the NLD, estimating the probability of their failure is difficult to determine. The extent of disaster that could occur is also difficult to determine for such levees for many reasons, including the fact that for many it is not known how high the water needs to rise before they are overtopped. However, at least we know the location of many more of these structures than we did a decade ago. In the future, these levees will be examined more thoroughly and added to the NLD, and we will have more information about their nature and risk characterization.

D. Summary of Vulnerability

1. *Dams*

A developing concern with dams is that Iowa's flood flows have been larger and more frequent in the last two decades. This subjects the structures to more stress than they were designed for and reduces the effectiveness of those specifically built for flood protection. Meanwhile, siltation is reducing low flow storage capacities and limiting recreational opportunities. Funding, especially for privately-owned structures is limited. Because of the potential for loss of life and property when a dam fails, each high-risk installation should have an emergency action plan (EAP) in place.

Until recently, Iowa was one of the few states that did not have the authority to require a dam owner of a high hazard potential dam to prepare an EAP. Fortunately, Iowa regulations have changed since the last update of the Iowa Hazard Mitigation Plan and now High Hazard dams must develop an EAP. But, it will still take some time for those that did not have one to come into compliance. So, as of 2023, only about two-thirds of the high hazard dams have EAPs.

The chart below shows which high hazard dams have EAPs and which ones do not. It also illustrates some other important factors relative to vulnerability to dam failure. The Population At Risk (PAR) is shown for several dams, but not all. A state-sponsored project, using FEMA and other funds, has recently been initiated to determine and document the PARs for all high hazard dams, but at this point not quite half of the dams have PARs determined. Soon, PARs will be available for all high hazard dams.

The chart also includes information garnered from several local hazard mitigation plans about the number of buildings that would be at risk from dam failure, as well as the estimated economic loss from a dam failure. Not all local hazard mitigation plans provide such impact information in numbers, so such data is lacking. However, it has been augmented with information from the USACE for dams which they own and operate.

Dam Name	**PAR** from DNR or USACE	**Est. # of Bldgs. At Risk** from Local Hazard Mit. Plans or USACE	**Estimated Economic Loss** from Local Hazard Mit. Plans or USACE	**NID ID**	**County**	**City**	**Condition**	**EAP?**
Greenfield Reservoir Dam	15			IA 02267	Adair	GREENFIELD	Satisfactory	Y
Prescott Flood Prevention Dam	38		$777,000	IA 01459	Adams	PRESCOTT	Rated Fair	Y
Rathbun Reservoir Dam	142-994	0	$9,129,895-39,179,042	IA 00016	Appanoose	RATHBUN	USACE Inspected	Y
Davids Creek Watershed Site 1B-2				IA 01470	Audubon	EXIRA	Satisfactory	Y
Littlefield Lake Dam				IA 01691	Audubon	ATLANTIC	Satisfactory	Y
Bamboo Ridge Lake				IA 04139	Black Hawk	Waterloo	Satisfactory	No
Fieldstone Addition Dam				IA 03436	Black Hawk	Cedar Falls	Satisfactory	Y
SW Branch Dry Run Creek Stormwater Detention Dam				IA 03547	Black Hawk	Cedar Falls	Satisfactory	No
Viking Road Detention Dam	1,040			IA 03104	Black Hawk	CEDAR FALLS	Rated Fair	No
Virden Creek Dam				IA 01972	Black Hawk	WATERLOO	Satisfactory	No
Storm Lake - Northeast Dredge Spoil Disposal Dam				IA 03546	Buena Vista	Storm Lake	Satisfactory	No

Dam Name	PAR from DNR or USACE	Est. # of Bldgs. At Risk from Local Hazard Mit. Plans or USACE	Estimated Economic Loss from Local Hazard Mit. Plans or USACE	NID ID	County	City	Condition	EAP?
Carroll Stormwater Detention Dam	274	909	$48,841,684	IA 02352	Carroll	CARROLL	Satisfactory	Y
Arbor Valley Lake Dam				IA 03905	Clarke	OSCEOLA	Satisfactory	Y
Grade Lake Dam	4			IA 01819	Clarke	OSCEOLA	Satisfactory	No
Pikes Peak Flood Control Dam				IA 02061	Clayton	MC GREGOR	Satisfactory	No
Siegel Flood Control Dam				IA 02062	Clayton	MC GREGOR	Satisfactory	No
Slaughter Flood Control Dam				IA 02063	Clayton	MC GREGOR	Rated Fair	No
Clinton Flood Control - First Congregational Church Dam		1	$54,165	IA 02329	Clinton	CLINTON	Satisfactory	Y
Clinton Flood Control - May Pond Dam		154	$9,664,096	IA 02328	Clinton	CLINTON	Rated Fair	Y
Clinton Flood Control - Springvalley Pond Dam		13	$1,757,079	IA 02827	Clinton	CLINTON	Satisfactory	Y
Clinton Flood Control - Whittier Dam		181	$15,732,331	IA 02826	Clinton	CLINTON	Satisfactory	Y
Meyer Dam	164			IA 01926	Crawford	DENISON	Rated Fair	No
Yellowsmoke Park Dam	12			IA 02014	Crawford	DENISON	Satisfactory	Y
Heritage Woods Dam		3	$586,380	IA 03548	Dallas	Van Meter	Satisfactory	Y
Maffitt Reservoir Dam	57	1	$364,575	IA 01338	Dallas	WEST DES MOINES	Satisfactory	No
Southfork Dam	95	16	$11,004,555	IA 02411	Dallas	CLIVE	Satisfactory	Y
Little River Watershed Site M-1	71	30	$34,850,000	IA 02263	Decatur	STATE OF MISSOURI	Satisfactory	Y
Schoenewe Dam	8			IA 02080	Des Moines	BURLINGTON	Poor	No
Zaiser Dam				IA 04148	Des Moines	Kingston (not incorporated)	Satisfactory	No
Carter Road Stormwater Detention Dam				IA 03512	Dubuque	Dubuque	Satisfactory	Y
Beeds Lake Dam	31			IA 01344	Franklin	HAMPTON	Rated Fair	Y
Hamburg Watershed Site M-1	181			IA 00392	Fremont	HAMBURG	Satisfactory	Y
Mill Picayune Watershed Site B-3				IA 00467	Harrison	DUNLAP	Satisfactory	No
Middle Pond Dam	7			IA 01699	Iowa	MIDDLE AMANA	Poor	Y
Leisure Lake Dam	7		$300,000	IA 00522	Jackson	FULTON	Satisfactory	No
Coralville Dam	736-24,712	0	$31,820,303-2,478,737,971	IA 00012	Johnson	IOWA CITY	USACE Inspected 2019	Y
Coralville Regional Detention Basin				IA 03397	Johnson	CORALVILLE	Rated Fair	Y

Dam Name	PAR from DNR or USACE	Est. # of Bldgs. At Risk from Local Hazard Mit. Plans or USACE	Estimated Economic Loss from Local Hazard Mit. Plans or USACE	NID ID	County	City	Condition	EAP?
North Branch Ralston Creek Dam	2,199			IA 02249	Johnson	IOWA CITY	Satisfactory	No
Oaknoll Dam				IA 02848	Johnson	IOWA CITY	Satisfactory	No
Scott Blvd Dam				IA 02117	Johnson	IOWA CITY	Satisfactory	No
West Branch Flood Control Dam				IA 04223	Johnson	West Branch	Satisfactory	No
Aegon Dam				IA 03081	Linn	CEDAR RAPIDS	Satisfactory	Y
Pleasant Creek Lake Dam	12			IA 02083	Linn	PALO	Satisfactory	No
Red Haw Dam	6	100	$10,855,079	IA 01357	Lucas	LAKE ELLIS	Rated Fair	No
Covered Bridge Estates Dam		3		IA 03516	Madison	Carlisle	Satisfactory	No
RED ROCK RESERVOIR DAM	2,880-27,459	1101 to 10,963	$81,822,131-1,790,751,240	IA 00013	Marion	CARLISLE	USACE Inspected 2022	Y
Pony Creek Watershed Site 21				IA 00675	Mills	PACIFIC JUNCTION	Satisfactory	No
Deer Creek Dam				IA 02937	Plymouth	SIOUX CITY	Satisfactory	Y
Focht & Schindel Dam	119			IA 00860	Plymouth	SIOUX CITY	Rated Fair	Y
Held Watershed Site E-3	103			IA 01857	Plymouth	HINTON	Poor	Y
Held Watershed Site E-4	120			IA 01856	Plymouth	HINTON	Rated Fair	Y
Big Creek Barrier Dam	--			IA 00018	Polk	POLK CITY	USACE Inspected 2022	Y
Big Creek Diversion Dam	53-552	0	$6,339,518-53,783,681	IA 00014	Polk	POLK CITY	USACE Inspected 2022	Y
Clive Lake Dam	293			IA 02456	Polk	CLIVE	Satisfactory	Y
Easter Lake Stormwater Retention Basin - Site 9				IA 03519	Polk	Des Moines	Satisfactory	Y
Fort Des Moines Park Dam	8			IA 01840	Polk	DES MOINES	Rated Fair	Y
Glen Oaks Country Club Dam	43			IA 04280	Polk	West Des Moines	Satisfactory	Y
Parkview Lake Dam	141			IA 02030	Polk	URBANDALE	Satisfactory	Y
Saylorville Reservoir Dam	2,668-49,791	0	$183,888,366 - 3,762,881,966	IA 00017	Polk	DES MOINES	USACE Inspected 2022	Y
Twenty-Sixth Street Stormwater Detention Basin				IA 03540	Polk	Des Moines	Satisfactory	No
West Lakes Office Park Dam	61			IA 02499	Polk	WEST DES MOINES	Satisfactory	Y

Dam Name	PAR from DNR or USACE	Est. # of Bldgs. At Risk from Local Hazard Mit. Plans or USACE	Estimated Economic Loss from Local Hazard Mit. Plans or USACE	NID ID	County	City	Condition	EAP?
Indiann Creek Watershed Site 2				IA 01664	Pottawattamie	COUNCIL BLUFFS	Satisfactory	No
Monument Road Dam				IA 04081	Pottawattamie	Missouri River	Satisfactory	No
Lake Cimarron		"several homes"		IA 04140	Poweshiek	Lake Ponderosa	Satisfactory	Y
Lake Ponderosa Dam	9	"several homes"		IA 00972	Poweshiek	SPRING VALLEY	Satisfactory	Y
Lake of the Hills Dam	1,786	1		IA 00978	Scott	DAVENPORT	Satisfactory	No
Lost Grove Lake				IA 04083	Scott		Satisfactory	No
South Ridge Estates - East Dam		220	$22,666,397	IA 03533	Sioux	Sioux Center	Satisfactory	No
Ames Basin #2		residential developmt.		IA 02392	Story	AMES	Satisfactory	Y
Ames Basin #3		residential developmt.		IA 02393	Story	AMES	Satisfactory	Y
Ames Basin #4		residential developmt.		IA 02394	Story	AMES	Satisfactory	Y
Creston Flood Prevention Dam	307			IA 01756	Union	CRESTON	Satisfactory	Y
Twelve Mile Creek Watershed Site M-1				IA 02194	Union	AFTON	Satisfactory	Y
Lake Sugema Dam				IA 02626	Van Buren	FARMINGTON	Satisfactory	Y
Jefferson Park Watershed Site 1	5			IA 01103	Wapello	OTTUMWA	Satisfactory	Y
Jefferson Park Watershed Site 10	2,944			IA 02314	Wapello	OTTUMWA	Satisfactory	Y
Jefferson Park Watershed Site 3	1,056			IA 01104	Wapello	OTTUMWA	Satisfactory	Y
Jefferson Park Watershed Site 4	89			IA 01105	Wapello	OTTUMWA	Satisfactory	Y
Jefferson Park Watershed Site 5	178			IA 02348	Wapello	OTTUMWA	Satisfactory	Y
Brushy Creek Dam	9			IA 03116	Webster	FRASER	Satisfactory	Y
Bacon Creek Watershed Site A-1-1	21			IA 01796	Woodbury	SIOUX CITY	Rated Fair	Y
Bacon Creek Watershed Site A-2-4	1,405			IA 01791	Woodbury	SIOUX CITY	Rated Fair	Y
Bacon Creek Watershed Site A-3	194			IA 01797	Woodbury	SIOUX CITY	Satisfactory	Y
Bacon Creek Watershed Site A-3-1	24			IA 01795	Woodbury	SIOUX CITY	Satisfactory	Y
Bacon Creek Watershed Site C-1	126			IA 01685	Woodbury	SIOUX CITY	Satisfactory	Y
Glen Ellen Subwatershed Site 3-1				IA 01254	Woodbury	BRONSON	Satisfactory	No
Glen Ellen Subwatershed Site 3-2				IA 01253	Woodbury	LUTON	Satisfactory	No
Smokey Hollow Subwatershed Site 1				IA 02311	Woodbury	SMITHLAND	Satisfactory	Y

Dam Name	PAR from DNR or USACE	Est. # of Bldgs. At Risk from Local Hazard Mit. Plans or USACE	Estimated Economic Loss from Local Hazard Mit. Plans or USACE	NID ID	County	City	Condition	EAP?
Smokey Hollow Subwatershed Site 2				IA 02312	Woodbury	SMITHLAND	Rated Fair	Y
Smokey Hollow Subwatershed Site 3				IA 02313	Woodbury	SMITHLAND	Satisfactory	Y
Smokey Hollow Subwatershed Site 4				IA 02310	Woodbury	SMITHLAND	Poor	Y

The chart is organized alphabetically by county name. Saylorville Reservoir in Polk County has both relatively high PAR and economic loss numbers. Other dams with PARs that exceed 2000 are: North Branch Ralston Creek in Johnson County, Red Rock Reservoir dam in Marion County, and a Jefferson Park watershed dam in Wapello County. It is important to note that PARs and loss estimates are not available for most of the dams. This is a significant deficiency in identifying vulnerability. As mentioned, a project is currently underway to address this deficiency through analysis that will determine PARs for more high hazard dams. This project will also gather additional risk assessment information. It will identify probable failure modes of dams with potential consequences. The analysis will also determine if additional studies are required for each dam to determine if potential rehabilitation is required for any unacceptable risks. Efforts have also begun to determine what structures are in inundation areas below each dam, and from this better economic loss data can be derived.

While vulnerability data is somewhat lacking, there are some conclusions that could be made about what areas are most vulnerable dam failures. First, note that only 38 counties in Iowa have high hazard dams within their boundaries. By definition, areas below High Hazard dams have greater vulnerability than areas downstream from Significant (aka Moderate) Hazard dams. Thus, the counties in the state that have the most vulnerability in relation to the hazard of dam failure are these 38 with high hazard dams:

Counties with High Hazard Dams

Adair	**Clarke**	**Dubuque**	**Johnson**	**Plymouth**	**Story**
Adams	Clayton	Franklin	Linn	Polk	Union
Appanoose	Clinton	Fremont	Lucas	Pottawattamie	Van Buren
Audubon	Crawford	Harrison	Madison	Poweshiek	Wapello
Black Hawk	Dallas	Iowa	Marion	Scott	Webster
Buena Vista	Decatur	Jackson	Mills	Sioux	Woodbury
Carroll	Des Moines				

Four particular areas are more vulnerable in the event of dam failure than other areas in the state. The areas below the four following dams have the greatest number of structures and/or value of structures that are vulnerable in the event of dam failure:

- Coralville Dam
- Rathbun Dam
- Red Rock Dam
- Saylorville Dam

All of these dams are U.S. Army Corps of Engineers (USACE) dams and hold much more water than any non-USACE high hazard dams in the state. The following table shows the water storage of these dams.[83]

Dam	Normal Pool Storage (in acre-feet of water)	Flood Storage Pool (in acre-feet of water)
Coralville	28,100	421,000
Rathbun	Up to 205,359	346,297
Red Rock	189,020	1,436,000
Saylorville	73,600	567,000

For the sake of comparison, the maximum storage capacity for most of the other high hazard dams in the state is less than 250 acre-feet. The greatest water storage for any other high hazard dam in the state is 35,500 acre-feet at another USACE dam at Big Creek, which actually flows into Saylorville. The next highest storage capacity for a high hazard dam in Iowa is 32,650 acre-feet (Little River Site M-1 in Decatur County). That is less than a tenth of the flood storage capacity of any of the four dams listed in the table. In other words, any of the four dams – Coralville, Rathbun, Red Rock, and Saylorville – can hold 1000 times more water than most of the high hazard dams and at least ten times the water of any non-USACE high hazard dam in the state. This very high comparative volume of water is one reason why vulnerability is greater below these dams as compared to elsewhere.

Another reason vulnerability below these four dams is greater is because of the development found below these dams. Because of the large volume of water held back by these dams, a failure of one would result in impacts that could be felt much further downstream as compared to other dams. Failure of the Red Rock Dam, for instance, would impact areas all along the rest of the Des Moines River some 140 miles to its confluence with the Mississippi, and could even have consequences to downstream areas as far as Saint Charles, Missouri[84]. Jurisdictions vulnerable to the dam's failure include Marion, Mahaska, Wapello, Van Buren, and possibly even Lee counties. Ottumwa, Eldon, Eddyville and other cities in those counties that border the Des Moines River would likewise be vulnerable. If the Red Rock Dam were to fail under a scenario in which the water level behind the dam was at the top of active storage[85], then the population at risk would be up to 22,100 and direct property damage is estimated to be $1.308 billion. If the dam failed at maximum high pool, the population at risk could be up to 27,500 and direct property damage up to $1.791 billion[86].

The population in Polk County within the probable inundation path of failure of the Saylorville Dam (holding near maximum storage) is estimated to be over 40,000[87]. The building values in that inundation path are estimated to be more than $1.9 billion[88]. Besides Polk County, other jurisdictions vulnerable to the failure of Saylorville Dam are

[83] http://www.mvr.usace.army.mil/Media/Fact-Sheets/ accessed May 16, 2018 and https://web.archive.org/web/20110723145716/http://www.nwk.usace.army.mil/ra/TheDam.cfm.
[84] USACE 2015. *Red Rock Dam Consequence Assessment Report.* (p. 11-13)
[85] The top of active storage (TAS) pool scenario corresponds to the highest elevation which can be obtained under normal regulated operating conditions for authorized purposes (i.e. without emergency spillway releases). Ibid. (p. 8)
[86] Ibid. (p. 33)
[87] Polk County, Iowa with AMEC Environment & Infrastructure, Inc. (2019). *Polk County, Iowa Multi-jurisdictional Hazard Mitigation Plan.* (p. 3.106 and 3.107)
[88] Ibid.

Warren County (northeast portion) and the cities of Ankeny, Carlisle, Des Moines, Johnston, Pleasant Hill, Runnels, Urbandale and West Des Moines.

Failure of the Coralville dam in Johnson County could also amount to hundreds of millions of dollars of property damage as it would result in flooding in Coralville and Iowa City, including many University of Iowa facilities[89]. If the Coralville Dam were to fail under a top of active storage pool scenario, then the population at risk would be up to 14,000 with direct property damage estimated to be $1.296 billion. If the dam failed at maximum high pool, the population at risk could be up to 24,700 with direct property damage up to $2.479 billion[90].

Rathbun Dam is less than 20 miles from the Missouri border, and inundation from its failure would actually have more impact on Missouri than Iowa. If the dam were to fail at maximum high pool, 64 structures in Iowa would be inundated (with a total of 590 including structures in Missouri). A failure at normal high pool level would inundate 23 structures in Iowa (plus another 234 in Missouri)[91].

The inundation impact information on failure of USACE dams is available from the USACE offices at Rock Island, Illinois and Kansas City, Missouri. Information on inundation due to failure of most of the other high hazard dams in Iowa is available from the Iowa Department of Natural Resources Dam Safety Program. The Dam Safety Program has just initiated a project to make this information available online to emergency management personnel. Only emergency management personnel, dam owners and certain others will have access to the inundation/evacuation maps, but a significant amount of information about every dam, high hazard or not, will be available to the entire public. This information is available to the public at https://iowadnr.knack.com/dams#public/. Emergency management personnel can view inundation maps for most high hazard dams in the state; however, inundation maps are not yet available for the following:

[89] Johnson County, Iowa with East Central Iowa Council of Governments (2019). *Johnson County, Iowa Multi-jurisdictional Hazard Mitigation Plan.* (p. 136).
[90] USACE 2014. *Coralville Dam Consequence Assessment Report.* (p. 23)
[91] USACE 2011. *Rathbun Dam Failure Inundation Map.*

High Hazard Dam (inundation/evacuation area not available July 2023)	County Name
Storm Lake - Northeast Dredge Spoil Disposal Dam	Buena Vista
Arbor Valley Lake Dam	Clarke
Grade Lake Dam	Clarke
Pikes Peak Flood Control Dam	Clayton
Siegel Flood Control Dam	Clayton
Slaughter Flood Control Dam	Clayton
Meyer Dam	Crawford
Maffitt Reservoir Dam	Dallas
Schoenewe Dam	Des Moines
Zaiser Dam	Des Moines
Mill Picayune Watershed Site B-3	Harrison
Leisure Lake Dam	Jackson
North Branch Ralston Creek Dam	Johnson
Oaknoll Dam	Johnson
Covered Bridge Estates Dam	Madison
Pony Creek Watershed Site 21	Mills
Big Creek Barrier Dam	Polk
Big Creek Diversion Dam	Polk
Big Creek Terminal Dam	Polk
IndIA n Creek Watershed Site 2	Pottawattamie
Lost Grove Lake	Scott
Ames Basin #2	Story
Ames Basin #3	Story
Ames Basin #4	Story

*2. **Levees***

Vulnerability to the effects of a disaster is not only related to the likelihood of an event, but also the people and assets that would be exposed to damage if the event occurs. Thus, to understand what areas are most vulnerable to levee failures, one must find out both where there are levees that may have increased probability of failure AND where the most people and greatest value of assets would be exposed in the event of the failure of such levees. In section C above, a chart was presented that showed where there are levees that have inspection ratings of "Unacceptable", or where there is no recent inspection, to identify levees that are more likely to fail than levees that have inspection ratings of "Minimally Acceptable" or "Acceptable". Below is a similar chart, but it also shows the estimated property value protected by each levee, as well as the "Population at Risk" (PAR), which is the number of people protected by the levee. The chart is organized alphabetically by county name. The chart does not include totals for levees that were rated as "Minimally Acceptable" or "Acceptable". (And so, if a county only has levees that are "Minimally Acceptable" or "Acceptable", it will not be found on the chart.) As some levee systems cross multiple counties, such levee systems will be listed on their own with the multiple counties in which they may be found.

CITY	COUNTY	Levee System Rating at Last Inspection				Combined Amount Rated "Unacceptable" or No Inspection Rating	
		Unacceptable		(blank)			
		PROPERTY VALUE	PEOPLE AT RISK	PROPERTY VALUE	PEOPLE AT RISK	Property Value	People at Risk
Waterloo	Black Hawk	$ 3,015,844,282	22785	$ 314,465,914	2091	$ 3,330,310,196	24,876
	Clayton	$ 8,420,170	20	$ 3,058,878	3	$ 11,479,048	23
	Clinton			$ 8,246,936	80	$ 8,246,936	80
	Crawford			$ 121,266,409	2	$ 121,266,409	2
	Dallas			$ 24,700,940	124	$ 24,700,940	124
	Des Moines			$ 10,484,977	11	$ 10,484,977	11
	Dubuque			$ 3,474,533	15	$ 3,474,533	15
	Fremont	$ 12,753,202	144	$ 437,249	3	$ 13,190,451	147
	Fremont, Atch	$ 164,715,090	984			$ 164,715,090	984
	Fremont, Mill	$ 37,259,250	155			$ 37,259,250	155
Missouri Valley mostly	Harrison			$ 324,576,398	1627	$ 324,576,398	1,627
	Harrison, Mo	$ 17,210,980	175			$ 17,210,980	175
	Harrison, Pottawattamie			$ 7,558,250	23	$ 7,558,250	23
	Ida	$ 59,126,650	450	$ 3,170,141	14	$ 62,296,791	464
	Iowa			$ 53,897,365	58	$ 53,897,365	58
	Jackson			$ 9,458,984	29	$ 9,458,984	29
	Johnson			$ 3,624,845	86	$ 3,624,845	86
Cedar Rapids	Linn			$ 2,888,166,158	13648	$ 2,888,166,158	13,648
	Marshall			$ 2,895,729	3	$ 2,895,729	3
	Mills	$ 49,398,181	612	$ 39,992,955	210	$ 89,391,135	822
	Monona	$ 92,594,961	416	$ 1,107,329	15	$ 93,702,290	431
	Monona, Wo	$ 8,270,101	42			$ 8,270,101	42
	Montgomery			$ 20,095,353	195	$ 20,095,353	195
	Muscatine	$ 42,265,480	198	$ 51,096,675	248	$ 93,362,155	446
	Polk			$ 14,525,862	42	$ 14,525,862	42
Council Bluffs	Pottawattam	$ 3,900,463,181	35794	$ 799,085,684	1339	$ 4,699,548,865	37,133
	Pottawattamie, Douglas					$ -	0
Riverdale & Rock Island Arsenal	Scott			$ 2,430,788,825	1794	$ 2,430,788,825	1,794
	Sioux	$ 86,056,098	704			$ 86,056,098	704
	Story			$ 236,377	2	$ 236,377	2
Ottumwa	Wapello			$ 971,926,077	3501	$ 971,926,077	3,501
	Warren					$ -	0
	Winneshiek	$ 117,555,000	959	$ 36,879,567	35	$ 154,434,567	994
Sioux City	Woodbury	$ 1,309,176,168	9460			$ 1,309,176,168	9,460

Darker shades of red are used to illustrate factors of greatest vulnerability. One can see that the darkest shade of red is found upon the numbers for Council Bluffs. The chart shows that property in Council Bluffs worth nearly

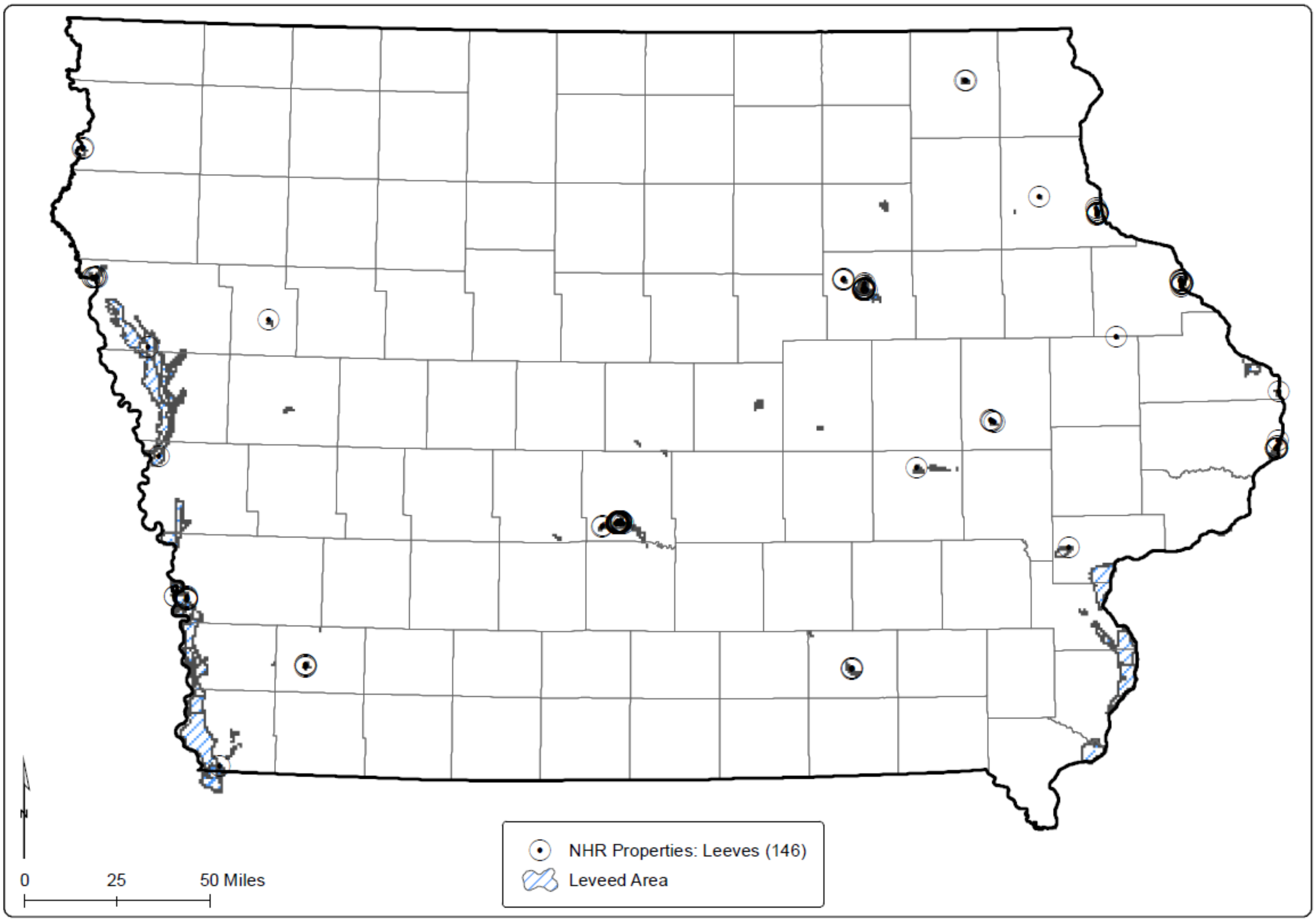
$4.7 billion is protected by levees that are either rated as "Unacceptable" or do not have a recent inspection rating. The number of people protected by such levees in Council Bluffs is over 37,000. Based on the figures in the chart, the second most vulnerable city would be Waterloo in Black Hawk County, followed by Cedar Rapids in Linn County. Sioux City in Woodbury County has the fourth highest population at risk, according to the chart, but the Riverdale and Rock Island areas in Scott County have the fourth highest property values protected by levees that are either rated as "Unacceptable" or do not have a recent inspection rating.

Note that these figures are relying solely on information available in the NLD. The counties listed here may have high vulnerability to levee failure because they have many miles of embankments (not found in the NLD) with little to no knowledge of what they protect or their condition:

Butler	Humboldt	Louisa	Muscatine	Tama
Emmet	Jasper	Lyon	Palo Alto	Winnebago
Fremont	Johnson	Mahaska	Plymouth	Wright
Hamilton	Keokuk	Marshall	Sioux	
Hancock	Kossuth	Mills	Story	

Property value and PAR are two ways of measuring what is at risk, but there are other assets that are not easy to measure in terms of dollars or human lives. For instance, many buildings, due to their historic nature, have value that cannot be measured in such manner. The location of buildings listed on the National Historic Register that are protected by NLD levees are shown on the following map.

Historic Buildings in Areas Subject to Levee Failure



E. Summary of Problems

*1. **Dam Failure***

With aging dams that may be under increased pressure from more frequent extreme precipitation events, it is even more important that dam owners and public authorities seek to ensure that emergency action plans are in place for high and significant hazard dams. By definition, if one of these dams were to fail, people would be in harm's way and/or valuable property would be destroyed.

Dam failure probability can be reduced with increased attention to sound design, quality construction, and continued maintenance and inspection. It is important to consider that over 40 percent of the dams in the Iowa are more than 50 years old (the design life of a dam). This reflects the need to consider and encourage dam failure emergency action plans for high and significant hazard dams in the state.

*2. **Levee Failure***

The 2022 *Iowa Statewide Levee Districts Study* (*Study)* identified several problems related to the risks that levees present in the state. Several of these issues have already been mentioned in the above sub-sections, particularly the

General Description and Location, Probability and Extent sections. A few additional details from the *Study* are presented here. These additional details relate to the lack of information about levees in the state (i.e. incomplete levee inventory), and to the financial burdens of maintaining reliable levees. (The reader should refer to the *Study* for a more complete report of all the problems regarding levees.) Presenting these narratives from the *Study* will help provide an understanding of the possible mitigation actions that will be explored in the next section.

Statewide Levee Inventory

Part of the intent of the *Study* was to establish a statewide levee inventory. While the *Study* provided an initial attempt to develop such a levee inventory, it was unable to get a complete inventory. As stated in the *Study*:

> There are significant discrepancies between the information found in the [National Levee] Database and the information being provided by levee sponsors. These discrepancies include the omission of levee features to the inclusion of levee systems that are no longer active. (p. 7)

Also, as described earlier, there are many levees, or non-levee embankments, scattered all over the state that are not documented at all in the NLD. While many of these are not serving the function of a levee, some are. Those that are must be identified, and basic information about them should be determined so that risks, costs and benefits will all be understood better. The *Study* recommends that a more sustained effort should be undertaken to more completely develop a statewide levee inventory. The *Study* says that this "effort would require on-site observations by qualified staff" (page 51) and that the inventory should provide "a comparable basic risk measure across all levees" (p. 7). It proposes that a scalable approach for collecting data for the inventory be considered that uses "a less a less expensive 'desktop' assessment method for levees with no population, buildings, or other identifiable assets behind them" (p.7).

Financial Struggles of Levee Districts

Another directive of the *Study* was to examine the current financial status of levee districts. The *Study* reported that "most levee districts across the state are struggling financially" (page 11). It stated:

> The majority of districts reviewed did not have enough revenue to cover their expenses. Assessments have not increased to offset expense increases. Levee districts have been significantly impacted by the depopulation of rural Iowa. The depopulation of rural levee districts means there are fewer landowners to carry the burden of the increasing costs making any increases in levee assessments a significant financial burden on the remaining landowners. Federal buyouts result in the removal of any purchased lands from the assessment base causing the cost to be redistributed to the remaining landowners. While the lands purchased as part of a state buyout program continue to pay levee assessments, they do not pay property taxes, reducing the revenues available to the county to maintain roads and other services found in the acquired areas."[92]

The *Study* explained how expenses have increased for levee districts, providing the following examples:

> A common problem experienced by levee sponsors is the requirement to replace corrugated metal drainpipes with concrete drainpipes in order to maintain their enrollment in the PL 84-99 program. Based on FEMA's definition of a standard useful life, which for both corrugated metal pipe and concrete structures is approximately 30 years, levees constructed prior to the 1990s have or are approaching replacement. The cost to replace a corrugated metal pipe with a concrete pipe is approximately one million dollars. Most levee districts have multiple corrugated pipes running through their levees.

[92] *Iowa Statewide Levee Districts Study*, December 2022. Page 11-12.

Another recurring expense for levee sponsors is the inspection of relief wells. Most of the levee systems along the Mississippi and Missouri rivers utilize relief wells to deal with seepage and help prevent sand boils. USACE requires relief wells be inspected by a professional engineer every five years. Multiple sponsors explained that it costs $5,000 - $10,000 each to have their relief wells inspected. The City of Council Bluffs levee system contains approximately 170 relief wells. Using a cost factor of $7,500 each, it costs the City $1,275,000 every five years to conduct these inspections. Another levee sponsor expressed their frustration with these inspections is not only the costs, but USACE's assertions that while a pump is working and passed the inspection, they (USACE) didn't think it is pumping enough water at a certain rate and want the pump replaced in order to remain in the rehabilitation program. Another issue affecting the financial condition of levees is the availability of vendors to complete inspections or repair work to comply with USACE standards. Multiple sponsors explained that they often have to go out of state to find vendors who are willing and able to adhere to USACE's standards for the work they are being asked to complete. USACE will not provide financial assistance because the levee is not active in PL 84-99 and FEMA will not provide financial assistance because the levee was constructed by USACE. [93]

It costs levee sponsors thousands of dollars every year to maintain their levees. Some of the typical levee expenses found include animal and vegetation control, administrative costs, election expenses, and professional services. Most counties charge the districts an administrative fee for the work completed on behalf of the levee district by the auditor and treasurer's offices. While usually a minor expense, districts have annual elections that have associated costs that go with them. As discussed earlier, hiring qualified professionals to deal with inspection requirements is another cost to the districts. Other professional services common to levee districts include hiring engineers to complete studies or make recommendations to address structural shortcomings. Engineers are often consulted during a high-water event and immediately following to address issues as they arise during the event. Levee districts often spend thousands of dollars annually on attorney fees. Attorney services may be required to review contract and engineering proposals, address access and right-of-way issues, or to deal with other legal disputes with landowners, local governments, the state and even the federal government. A relatively new expense is that of contracted labor. Districts have used contract labor for years on major projects, but as local populations age and decline in number, many districts have turned to contract labor to handle more routine maintenance activities that were previously completed by trustees or other landowners. [94]

Federal assistance is normally provided through USACE or FEMA. Ideally, the levee is active in the USACE rehabilitation program, PL 84-99, and USACE will conduct emergency repairs, restoring the levee to its pre-disaster status. While USACE covers most of the expense, levee sponsors must provide the necessary borrow material to fill any breaches as well as ensuring USACE has access to the sites they need to make repairs. Providing borrow material can be a significant expense for the district, often costing the district $15 to $35 per cubic yard of material. Most projects will require tens of thousands of cubic yards of borrow material costing the local sponsors hundreds of thousands of dollars in expenses. . . . If a federally constructed levee has fallen out of the PL 84-99 program, USACE will not provide any financial assistance to the district nor will FEMA. Because the levee was constructed using federal funds, FEMA is prohibited from using their programs to provide financial assistance. [95]

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[93] *Ibid.* Page 14.
[94] Ibid. Page 14-15.
[95] Ibid. Page 17.

> Levee district trustees universally expressed their concern and frustration with increasing regulatory requirements coming from USACE. One of the new requirements we frequently heard about was the requirement to conduct a video inspection of pipes and other drainage structures. USACE requires that the video include the entire structure from one end to the other. This is a challenge as most of these structures have water passing through them constantly. In order to comply with the requirement, sponsors must pay to dam off the structure in order to drain the structure to be able to video the bottom of the structure. Another common frustration reported was the electronic testing of pumps. We often heard frustrations from sponsors
>
> that pumps that are working fine and performing as intended but fail this test and USACE wants them replaced. These new requirements are extremely technical and require trustees to hire companies to complete these requirements."[96]

Lack of a strategic plan to address multiple levees AND other flood mitigation options in a comprehensive fashion

Sometimes, perhaps too frequently, issues and problems of a community and their flood issues are not considered in relation to other places and factors, and a singular focus on a levee solution is prematurely decided upon. The Study provides the following example of how funding decisions were made that may have been changed had there been a more comprehensive and strategic plan:

> The following example is based on hindsight and all information available to us may or may not have been available to the Flood Mitigation Board at the time applications were approved. In early 2020, the Flood Mitigation Board took applications for projects related to Disaster 4421 with total funding of $21 million dollars available. Applications were received from 49 potential applicants with 26 applicants being awarded funding for projects. The FMB awarded $4,427,650 to the Coulthard Levee District to repair an existing breached levee that protects sparsely populated farmlands and I-29 by tying in the high ground along the south side of US Highway 30 to the Vanman Levee. The FMB chose not to award a $5,013,895 project to re-establish an abandoned levee that would protect the same areas as the Coulthard Levee PLUS the DeSoto Refuge and additional farmland west to the US Highway 30 Bridge at Blair Nebraska. Completion of the Rand Peterson project would provide continuous levee protection along the Missouri River from Blair, Neb., to the Boyer River. By not funding the Rand Peterson Project, the Coulthard and Vanman levee projects that were funded by the FMB will be put at risk of failure from floodwaters flowing through the Rand Peterson's project area. A strategic plan prepared in advance that took a holistic view of the area would have likely identified the benefits of funding the Rand Peterson project over the Coulthard project. [97]

F. Identification of Possible Actions to Mitigate Problem

The assessment and analysis above for the dam and levee failure hazard has hinted at several actions that would make Iowa more resilient in the event of a dam or levee failure disaster. In relation to dams, a key strategy already underway is to complete and exercise Emergency Action Plans (EAPs) for all of the high hazard dams in the state.

Also, as previously mentioned, risk assessments are already underway for several dams. The analysis from such assessments will determine if additional studies are required for each dam to determine if potential rehabilitation is required for any unacceptable risks. At that point, efforts will need to ensue to fund and implement such rehabilitation.

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[96] Ibid page 20
[97] Ibid page 48-49

As for levees, the 2022 *Iowa Statewide Levee Districts Study* recommended several actions that could be taken to address the issues discussed above. The following are key hazard mitigation proposals from the *Study:*

1. ***Invest in new infrastructure with fewer maintenance requirements***

The value of investing in new infrastructure that requires less maintenance is explained on page 15 of the *Study:*

> Some districts have found ways to overcome at least some of their financial challenges by coming up with creative ways to address recurring costs and/or generate income for the district. The City of Council Bluffs faces a recurring relief well inspection cost of approximately $1,275,000 over a five-year period. To help reduce this cost the City is currently expanding its use of seepage berms to replace relief wells where they can. The City is investing in new infrastructure that has fewer maintenance requirements in order to replace another piece of infrastructure with higher recurring costs. When completed, the City should reduce the number of relief wells from 170 down to 54 saving the City approximately $870,000 in inspection costs over that same five-year period.

2. ***Invest in employees and equipment***

The *Study* provides this explanation of this strategy (page 15)*:*

> Some districts have chosen to invest in employees and equipment in order to conduct their maintenance and project work in-house. The two largest districts examined, Little Sioux Inter-County Drainage District and the Two Rivers Levee & Drainage District both have multiple employees and equipment to conduct maintenance work within the district. Both districts have average annual revenues in excess of $800,000 and maintain embankment lengths close to 100 miles each.

3. ***Use different assessment methods for funding levee districts***

From the *Study*:

> The future of levee funding varies greatly depending on the levee's location. Urban levees and rural levees near expanding urban areas generally have a large enough assessment base to enable them to maintain their infrastructure. Some districts are taking advantage of the code to transition to an assessed value assessment method, which allows them to take advantage of the higher value of commercial, and industrial properties located within the district. Agricultural and rural levees face significant funding challenges under the current assessment method due to decreasing assessment bases and reducing likelihood that districts will qualify for any type of federal financial assistance. There needs to be a concerted effort to identify alternative assessment methods of funding agricultural and rural levees to provide sufficient funding to maintain these levees. If sufficient funding cannot be obtained to maintain the levees, they will become inactive in the PL 84-99 rehabilitation and WHEN they fail, there will be no financial assistance available to repair them. [98]

[98] Ibid. Page 22

*4. **Complete Levee Assessment & Inventory, then maintain through monitoring***

The *Study* recommends that "the General Assembly authorize additional funding to continue development of the inventory" that would include validating the information found in the NLD." The *Study* also advises consideration of the following when developing a more complete inventory:

- Prioritize levees where owners have volunteered to participate in inspections and assessments
- Ensure levee owners understand the information collected, potential uses, and how they can revise or manage the information

The *Study* also recommends establishing a **Levee Monitoring Program:**

> The General Assembly should consider the establishment of a statewide levee-monitoring program as part of a state levee safety program. The intent of the monitoring program is to identify levee systems in danger of structural failure and provide the financial assistance needed to prevent that failure. This would be achieved by monitoring USACE inspection reports, maintaining communication with levee sponsors and USACE, as well as requiring the submission of annual reports."[99]

Actually, the state Legislature has already acted upon this recommendation. Legislation was passed in early 2023 to create and fund an Iowa Levee Safety Office to be housed in the Department of Homeland Security and Emergency Management (HSEMD). Among other things, the legislation directs the Levee Safety Office, in cooperation with the Iowa Geological Survey, to conduct a statewide analysis of the condition of the state's levees. Based on such analysis, the Office and Survey are then to "identify each levee requiring repair or reconstruction based on a scale adopted by the Office which assigns a number based on the levee's critical need." [100] The legislation directs HSEMD's Levee Office to use such information to prepare a statewide levee assessment report and submit it to the governor and general assembly by January 5 of each year.[101]

*5. **Consolidate Levee Districts at the USACE System Level***

Concerning this recommendation, the Study explains:

> District consolidation at the system level provides the new district with more financial resources with minimal impact to the landowners living within the district. The consolidated district is able to fund projects that the smaller districts could not. This would allow for economy of scale advantages. These advantages could include purchasing power, the ability to hire administrative and maintenance employees, and increased trustee pool. Enrollment in USACE's rehabilitation program is determined at the system level so it makes sense for the system to be managed by a single board of trustees as opposed to multiple segment level boards because if one segment fails, the entire system fails.[102]

[99] Ibid. page 52
[100] Iowa Code 418A.4
[101] Iowa Code 418A.6
[102] *Iowa Statewide Levee Districts Study*, December 2022. Page 45

6. *Encourage a watershed approach to levee management*

As explained in the *Study,* flood risk reduction pursued at a watershed scale "provides an opportunity for all entities along a watershed to work together to achieve the desired effects that could not be achieved individually."[103] Also, when flood risk reduction investments are made in the watershed in a carefully considered and strategic way, "limited financial resources are applied to those projects that provide the most return on investment", as explained on page 25 of the *Study.* Or, put another way, money "strategically invested in mitigation projects in the upper watershed projects have the potential to save millions of dollars in repairs and future projects in the lower watershed."[104] The *Study* also provides these additional details:

> Levee and drainage districts should be encouraged to participate in available watershed management authorities and if not currently available, they should work with neighboring districts and communities to form one. . . . While legislation establishing WMAs specifically states flood risk reduction, flood risk education, and flood mitigation are objectives of the authorities, most WMAs are focused almost exclusively on water quality issues. The current legislation on WMAs does not specifically state that levee districts are eligible for membership; however, they are generally considered a political subdivision of the State when applying for federal and State assistance. The advantage to this type of approach is the holistic approach to flood risk mitigation. Multiple smaller projects along the length of the river can have a cumulative effect, reducing the risks for everyone within the watershed. Smaller projects are generally cheaper to install and maintain, while taking pressure off the larger more maintenance intensive features further downstream. This type of approach allows for the sequencing of projects to achieve the maximum benefits with the minimum costs. If an upstream project can reduce river levels, downstream levees may not need to be raised to experience less saturation that leads to maintenance issues."[105]

7. *Establish a state levee safety program*

The *Study* also recommends establishment of a state levee safety program. As explained on pages 23-24 of the *Study*:

> As part of the legislation for the National Levee Safety Program, Congress envisions that state levee safety programs would adopt and implement consistent national levee safety program practices; be able to help receive federal assistance in support of levee safety; carry out public education activities to improve awareness of flood risk; and collect and share levee information using the National Levee Database. In addition, there is opportunity for state levee safety programs to: help build capacity in levee owner/operators to inspect, assess, repair and rehabilitate levees; collaborate across programmatic and political jurisdictions to ensure all levees have adequate oversight; and apply services in a fair and equitable way across the landscape with special attention to disadvantaged communities, tribes, and individuals particularly vulnerable to flooding.

The *Study* further elaborates on pages 47-48:

> An integrated approach to levee safety requires each entity (federal, state, tribe, levee owner/operator), and communities to understand and fulfill their responsibilities and to do so in coordination with each other. It is envisioned that the lynchpin to success is having states serve in a key integrator role. . . . As part of the legislation for the National Levee Safety Program, Congress envisions that state levee safety programs would adopt and implement consistent national levee safety program practices, be able to facilitate federal assistance in support of levee safety, carry out public education activities to improve awareness of flood risk, and collect

[103] Ibid. page 23
[104] Ibid. page 25
[105] Ibid. pages 46-47

> and share levee information using the National Levee Database. In addition, there is opportunity for state levee safety programs to: help build capacity in levee owner/operators to inspect, assess, repair and rehabilitate levees; collaborate across programmatic and political jurisdictions to ensure all levees have adequate oversight; and apply services in a fair and equitable way across the landscape with special attention to disadvantaged communities, tribes, and individuals particularly vulnerable to flooding. The development of a state levee safety program provides an opportunity for the state to collect information and monitor the status of levees across the state, which is not currently being done. A state levee safety program can serve as an intermediator between the local levee districts, state agencies and the federal government. In this role, a state levee safety program can advocate on behalf of the levee district and assist them on compiling information requirements to obtain federal funding similar to how the Iowa Department of Homeland Security and Emergency Management (HSEMD) does with FEMA. A state program can also attempt to address the differences in federal guidance between USACE districts. Other states have used this type of program to help monitor compliance with USACE and FEMA regulatory requirements by establishing annual reporting requirements.
>
> A state department or agency responsible for the state levee safety program would be positioned to take a holistic approach to flood mitigation efforts across the state and develop a strategic plan for building, maintaining and rehabilitating levees across the state. The responsible agency would be positioned to coordinate or synchronize statewide flood mitigation efforts"[106]

As mentioned earlier, the state Legislature has already acted upon recommendations of the *Study,* and that includes this one. Legislation passed in early 2023 created and funded an Iowa Levee Safety Office that has some (though not all) of the abilities and responsibilities described in this sub-section.

8. Develop a comprehensive statewide strategic plan for flood risk

The *Study* makes a recommendation for levees which coincides with a similar recommendation for addressing flooding using other flood mitigation options. The recommendation is to develop a comprehensive strategic plan for flood risk reduction for the entire state. Such a strategy, that addresses the unique issues and resources of specific locations throughout the state, would identify the types of flood mitigation methods, whether levees or other methods, that are best suited for different areas. This recommendation for a comprehensive strategic plan is explained in more detail on pages 48-49 of the *Study*:

> Given the extensive planning and expense to establish and maintain a levee there needs to be a comprehensive approach to making these decisions. Often under the current management method, a local need is identified and a plan is developed to meet that immediate need without regard for the second and third order effects of that decision. Because these projects are often cost prohibitive without state or federal assistance, local governments are competing for limited state and federal resources to build and maintain their structures. Because these resources are limited, there needs to be a reasoned, thought-out approach to issuing financial support other than funding the squeaky wheel.
> . . . . A strategic plan should be developed at the district, watershed management authority (WMA) and the State level. These plans need to be communicated to residents at the appropriate level and they need to be coordinated among the various levels of government as well as with neighboring districts. Because the levee-related financial needs far exceed the available resources, it is important to identify the projects that can provide the greatest benefits that maximize the available funding. Communicating strategic plans at the county, WMA and State levels helps leaders at all levels to identify the scope of the

[106] *Iowa Statewide Levee Districts Study*, December 2022. Pages 47-48

> problems and work together to generate the financial resources required to address issues. There will likely never be enough available funding to address all the needs. Strategic planning at the WMA and State levels provides an opportunity for the sequential funding of projects to achieve the desired long-term results that may not otherwise be achieved through random awarding of flood mitigation projects. [107]

9. Encourage use of Councils of Government to complete administrative requirements

The *Study* explains this recommendation for levee districts in this way:

> Levee sponsors statewide are struggling to keep up with new and burdensome regulations to maintain their enrollment in federal rehabilitation programs. The time and effort required to complete and stay current on requirements exceeds the time available to the average trustee who is trying to operate and maintain their farm or business. To relieve some of this administrative burden, levee and drainage districts could tap into an already existing resource, which is the local council of government or COG. Formed more than 45 years ago, COGs provide regional planning and technical assistance to local governments and the communities in their region. . . . [COGs] are experienced in working with local, state and federal agencies to obtain financial resources and meet regulatory requirements. This experience would greatly benefit most districts especially as they transition to less experienced trustees. [108]

3.3.8. Landslide

A. General Description

Landslides occur when susceptible rock, earth, or debris moves down a slope under the force of gravity and water. Landslides may be very small or very large, and can move at slow to very high speeds. A natural phenomenon, landslides have been occurring in slide-prone areas of Iowa since long before the state was created. Landslides can occur due to rainstorms, fires, or human activities that modify slope and drainage.

B. Previous Occurrences

Reporting of landslide events in Iowa is sporadic. No state agency collects and maintains reports of landslides in Iowa. Recently the USGS published and posted an inventory of known landslides, but as stated in the summary of the publication, such “inventories are typically collected and maintained by different agencies and institutions, usually within specific jurisdictional boundaries, and often with varied objectives and information attributes or even in disparate formats[109]”. The few Iowa events included in this U.S. Landslide Inventory[110] included road or railroad closures from debris, with two involving train derailments and one a car crash. One event near Fort Madison involved a stretch of at least 300 feet of railroad tracks, with the debris six to ten feet deep.   As no State agency documents historical data on landslides in Iowa, there may be additional undocumented events, perhaps even larger than those described here. There have been no reported landslide events in Iowa resulting in death.

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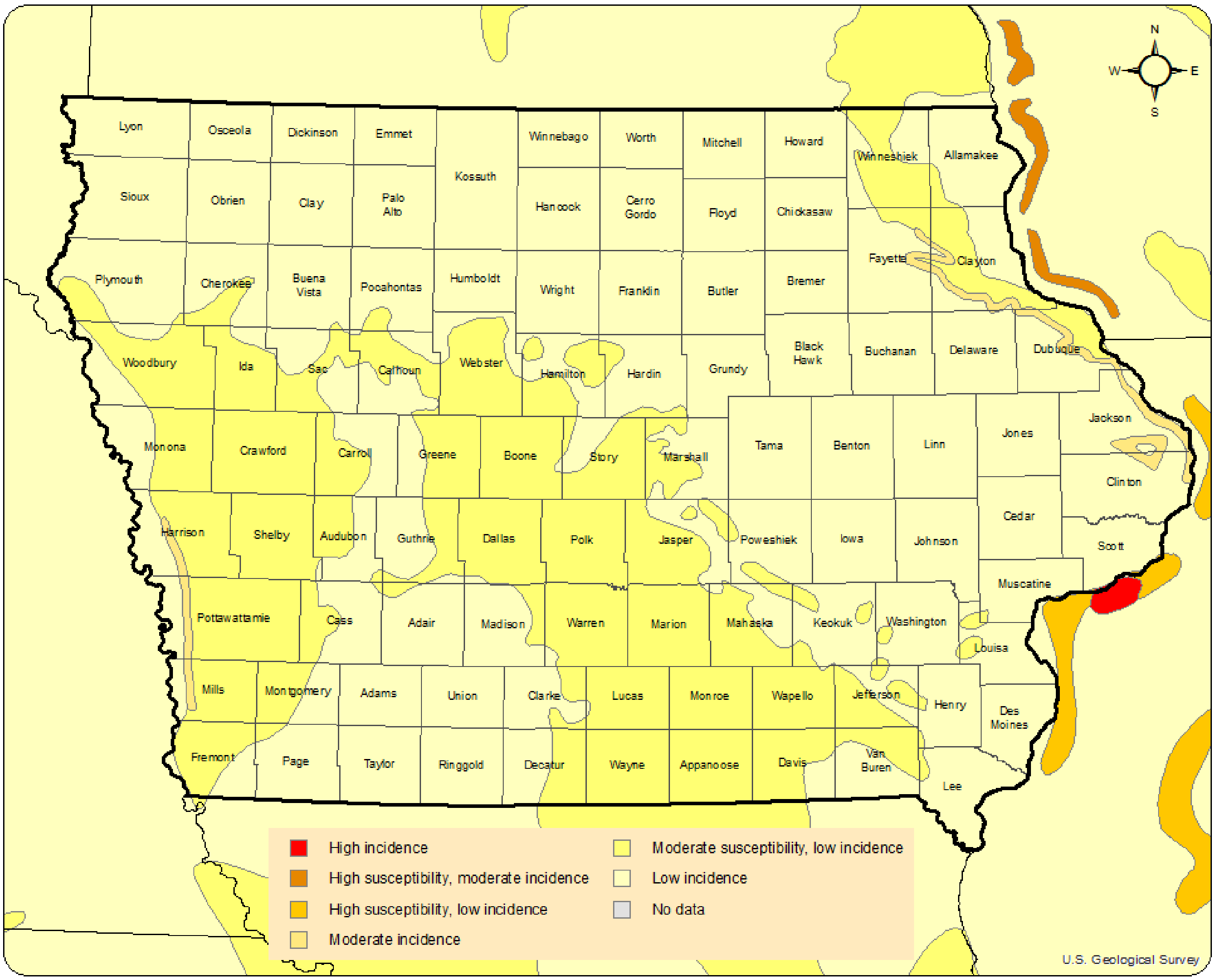
[107] Ibid. pages 48-49
[108] Ibid. page 49.
[109] Belair, G.M., Jones, E.S., Slaughter, S.L., and Mirus, B.B., 2022, Landslide Inventories across the United States version 2: U.S. Geological Survey data release, https://doi.org/10.5066/P9FZUX6N
[110] https://usgs.maps.arcgis.com/apps/webappviewer/index.html?id=ae120962f459434b8c904b456c82669d

C. Location, Probability, and Intensity

A portion of the state is moderately susceptible to landslides. In northeastern Iowa, along the Silurian Escarpment, you can find blocks of dolomite slumped onto the underlying Maquoketa shale. In the hilly terrain of central Iowa, areas of Pennsylvanian shale are susceptible to slides where it is overlain by loess or till. Susceptible areas are found along the adjacent steep terrain associated with the major river valleys such as the Mississippi, Missouri, Des Moines, and Iowa, and in the Loess Hills of western Iowa. The accompanying map shows the relative difference in landslide susceptibility and incidence for different areas of Iowa.

Landslide Incidence and Susceptibility. Source: USGS

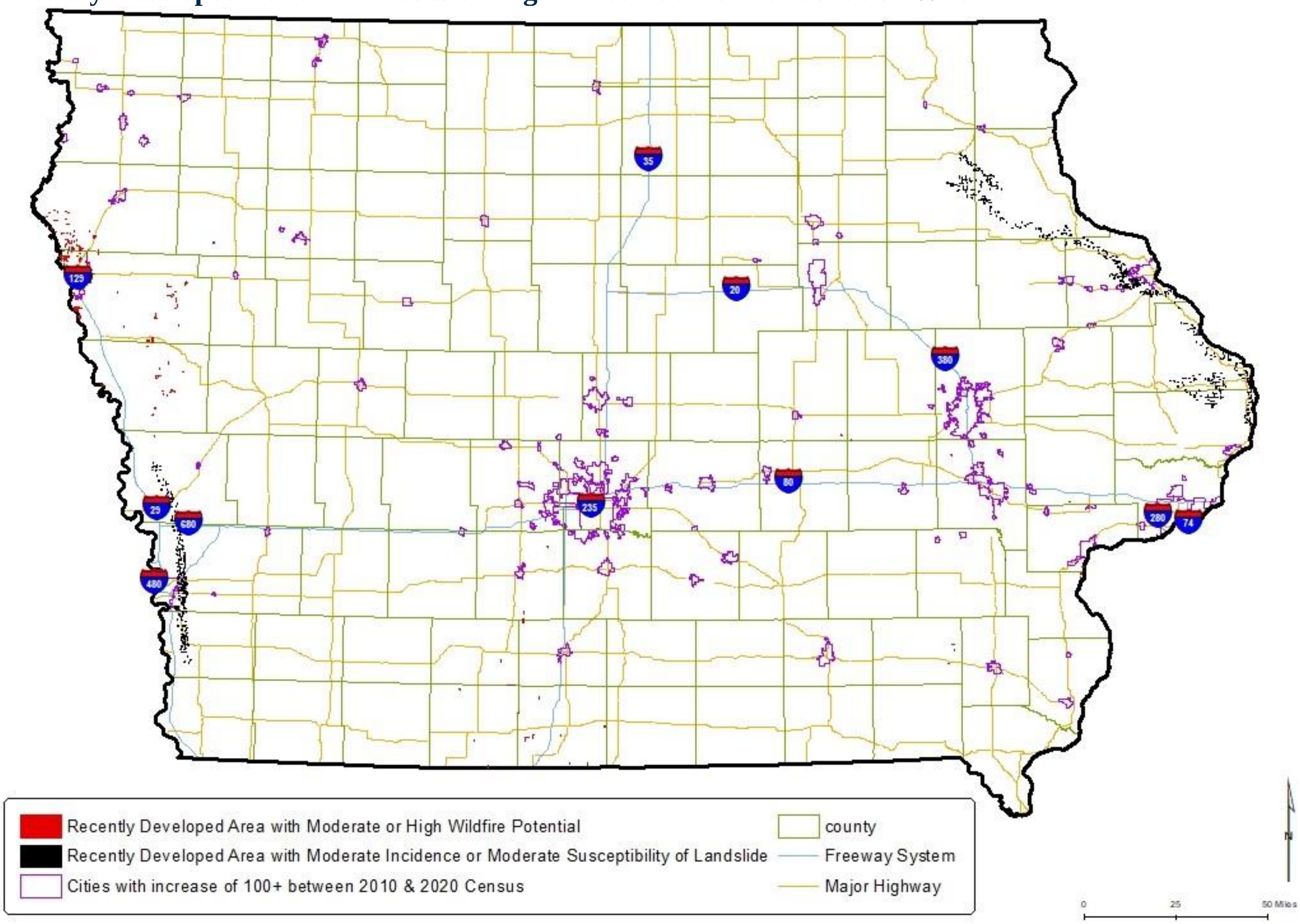


D. Summary of Vulnerability and Problem, and Identification of Possible Actions to Mitigate Problem

Of the areas of the state shown on the map above with "Moderate incidence" or "Moderate Susceptibility" of landslides, the areas in eight counties may becoming more vulnerable to damage because of development. The counties which have development in or encroaching upon those "Moderate incidence" or "Moderate

Susceptibility" areas are Fayette, Clayton, Dubuque, Jackson, Clinton, Harrison, Pottawattamie and Mills (see map below).111 However, no potential loss estimates can accurately be determined because, as no State agency documents historical data on landslides, no base data is available from which to develop estimates.

Recently Developed Land in Areas with Higher Potential for Landslide or Wildfire



FEMA's National Risk Index (NRI) tells a different (but not incompatible) story with its map of expected annual losses (EAL) due to landslides. The NRI estimates the highest EAL for Allamakee, Clayton, and Woodbury counties, which each have an EAL between $100,000 and $150,000. Four counties have EALs between $90,000

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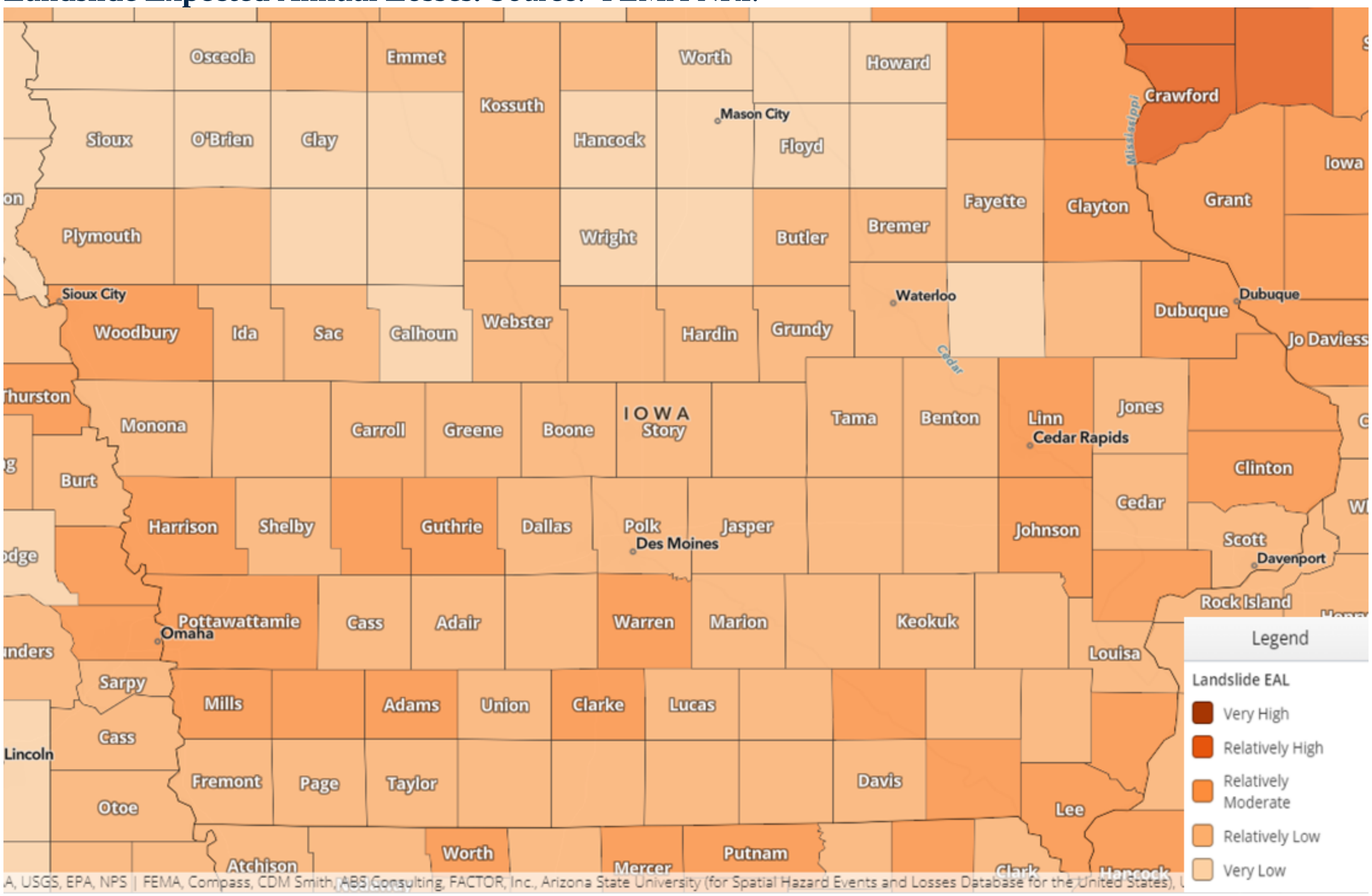
[111] Areas of recent development were derived from a comparison of USDA Crop Data Layer (CDL) maps. The CDL includes land categorized as "Developed". By comparing what land is currently "developed" as opposed to what was "developed" ten or twelve years ago, we can ascertain the areas that have recently been developed. The map shows land in black that has recently changed from undeveloped (in 2010) to developed (in 2022) based on the CDL, and also is in an area with higher potential for landslides.

and $100,000: Des Moines, Lee, Harrison, and Dubuque. The Landslide EAL for the entire state, inclusive of all counties, is $2,878,870 (as of December 2022, per the FEMA NRI at https://hazards.fema.gov/nri/map).

Landslide Expected Annual Losses. Source: FEMA NRI.



While maps show that there are areas of the state that may be somewhat susceptible to landslides, this is currently not a hazard that has had much impact. At least, jurisdictions have not reported any significant losses to landslides. In order to avoid increasing their susceptibility to damage from landslides, it would be wise for jurisdictions in the areas of moderate and higher landslide susceptibility to include in their land use codes a requirement that developers look carefully at the potential for landslides at specific sites, or a restriction on development in landslide-prone areas. This seems to be even more warranted because of evidence that extreme rain events, which could trigger landslides, appear to be occurring more frequently in Iowa.

Another potential mitigation action is to ensure proper drainage above, around, and beneath roads where landslides are most likely (e.g., by having sufficiently sized culverts).

3.3.9. Earthquake

A. General Description

An earthquake is any shaking or vibration of the earth caused by the sudden release of energy that may impose a direct threat on life and property. It is a sudden, rapid shaking of the earth caused by the breaking and shifting of rock beneath the earth's surface. This shaking can: cause buildings and bridges to collapse; disrupt gas, electric, and phone service; and sometimes trigger landslides, flash floods, and fires.

Instrumental Intensity	Acceleration (g)	Velocity (cm/s)	Perceived shaking	Potential damage
I	< 0.000464	< 0.0215	Not felt	None
II–III	0.000464 – 0.00297	0.135 – 1.41	Weak	None
IV	0.00297 – 0.0276	1.41 – 4.65	Light	None
V	0.0276 – 0.115	4.65 – 9.64	Moderate	Very light
VI	**0.115 – 0.215**	**9.64 – 20**	Strong	Light
VII	**0.215 – 0.401**	**20 – 41.4**	Very strong	Moderate
VIII	**0.401 – 0.747**	**41.4 – 85.8**	Severe	Moderate to heavy
IX	**0.747 – 1.39**	**85.8 – 178**	Violent	Heavy
X+	> **1.39**	**> 178**	Extreme	Very heavy

The accompanying chart helps illustrate the correlation between the Modified Mercalli Intensity rating, peak ground acceleration, perceived shaking and potential damage.

B. Previous Occurrences

Iowa as a whole has experienced the effects of few earthquakes in the past 175 years. The epicenters of 13 earthquakes have been located in the state[112], with the majority along the Mississippi River. The first known occurrence was in 1867 near Sidney in southwest Iowa[113]; the most recent occurrence was in 2004 near Shenandoah[114] in the southwest part of the state. The largest earthquake (Mercalli magnitude VI) was near the border of Illinois in the Davenport and Quad Cities area in 1934. While more than 20 earthquakes have occurred in or around Iowa over the past 175 years they have not seriously impacted the state. Many other earthquakes, with epicenters far from Iowa, are occasionally felt in Iowa but cause no damage. For example, a 5.6 magnitude earthquake centered in Oklahoma was felt within Iowa in 2016, but caused no damage. The strongest earthquake in Iowa, the one that occurred near Davenport in 1934, only resulted in slight damage.

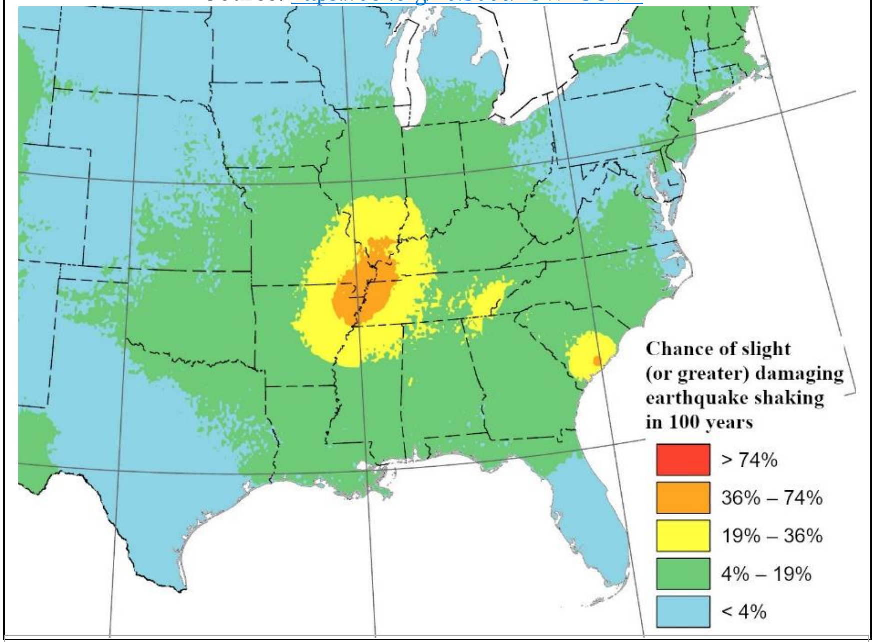
[112] https://www.iowadnr.gov/About-DNR/DNR-News-Releases/ArticleID/1033/Why-don%E2%80%99t-we-have-earthquakes-in-Iowa
[113] https://iowageologicalsurvey.org/hazards/
[114] https://www.volcanodiscovery.com/earthquakes/iowa/largest.html

C. Location, Probability & Intensity

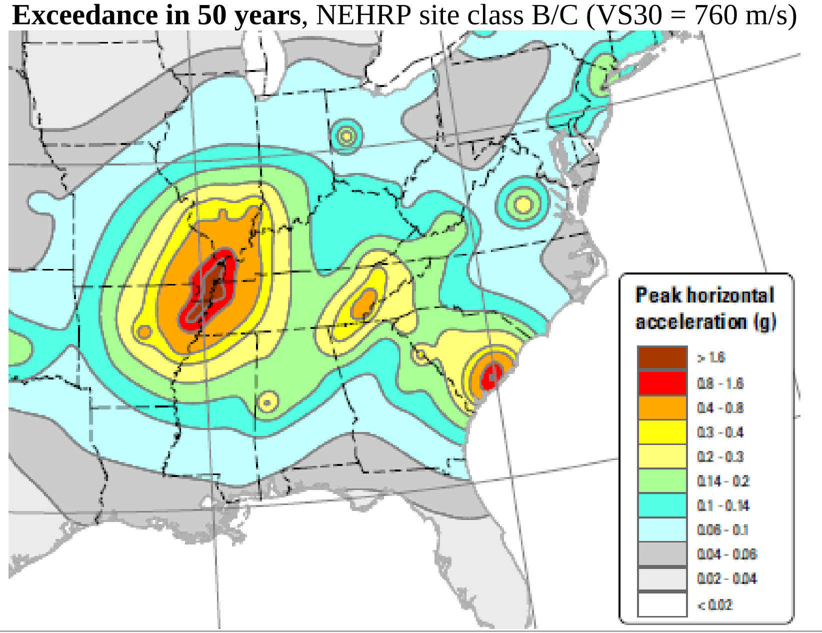
The adjoining earthquake probabilistic map illustrates the probability of a damaging earthquake in Iowa. It shows a low probability that Iowa would experience a damaging earthquake event (meaning a Modified Mercalli Intensity of VI or higher). This does not mean that Iowans would not feel shaking on occasion, but in all likelihood, whatever earthquake shaking is felt in Iowa would be vibrations similar to the passing of a heavy truck and at most result in rattling of dishes, creaking of walls, and swinging of suspended objects.

The map shows that portions of southeast Iowa have a greater risk of damage than the rest of the state. Southeast Iowa has between a four and nineteen percent chance in 100 years of experiencing an earthquake with shaking rated as VI in Modified Mercalli Intensity (MMI), which would cause light damage. The probability over 50 years is much less, as illustrated in the next map. An MMI VI rating equates to peak horizontal acceleration of at least 0.115 g, and the map shows that only a very small corner of Iowa, perhaps Lee County and a portion of neighboring counties, would have a 2 percent chance of experiencing peak horizontal acceleration of up to 0.1 g (which would cause less damage than the minimum 0.115 g experienced in a MMI VI earthquake).

Chance of Minor Damaging Earthquake Shaking[115] in 100 years
Source: https://doi.org/10.5066/P9WT5OVB[116]



Peak Horizontal Acceleration with a 2% Probability of Exceedance in 50 years, NEHRP site class B/C (VS30 = 760 m/s)



D. Summary of Vulnerability and Problem and Identification of Possible Actions to Mitigate Problem

Specific parts of Iowa could sustain different levels of damage due to the soundness and number of structures in an area, and the magnitude and origination point of the earthquake. FEMA's NRI tried to account for similar factors in its estimates of Expected Annual Losses (EALs) for counties in Iowa. The

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115 Shaking is equivalent to MMI VI and is based on the average 1-second horizontal spectral response acceleration and peak ground association. Ground-motions are amplified using topographic-based V_{S30} values.
116 Rukstales, K.S., and Petersen, M.D., 2019, USGS Data Release for 2018 Update of the U.S. National Seismic Hazard Model. Map retrieved from https://www.sciencebase.gov/catalog/item/5d55d0a5e4b01d82ce8eafa9.

NRI's Earthquake EAL calculations consider exposure, annualized frequency and historic loss ratio.[117] According to the NRI, only Scott County and Polk County have EALs above $100,000 each; the rest all fall under $70,000 each.

The adjoining table shows the EALs of the ten counties most vulnerable to earthquake damage (based on annualized loss). Earthquakes are not as serious a concern as other hazards in Iowa; of all the hazards profiled in this Plan that have EALs calculated, only the Wildfire hazard has a total statewide EAL lower than that of Earthquakes. Nevertheless, counties should be aware of the risk and determine to what degree and in what manner they wish to prepare.

Top 10 Counties in Iowa Most Vulnerable to Earthquakes, per NRI Expected Annual Loss (EAL)	
County	**Earthquake EAL**
Scott	$ 130,635
Polk	$ 116,443
Linn	$ 68,902
Des Moines	$ 52,801
Johnson	$ 44,201
Lee	$ 36,214
Clinton	$ 32,632
Woodbury	$ 31,072
Muscatine	$ 29,935
Black Hawk	$ 27,659
Entire State (all 99 counties)	**$ 1,024,407**

3.3.10. Wildland Fire or Grass Fire

A. General Description

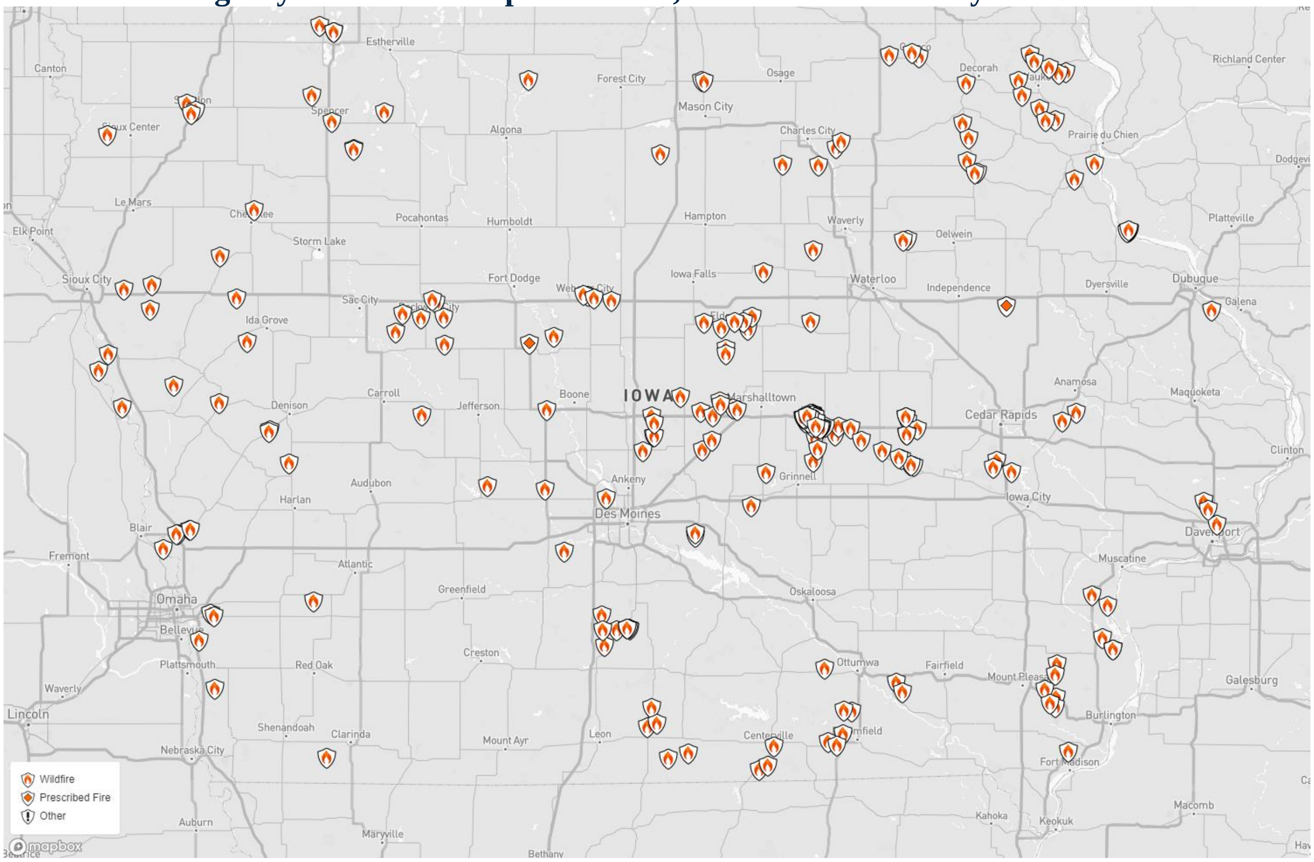
A grass fire or wildland fire is an uncontrolled fire that threatens life and property in a rural or wooded area. A grass fire or wildland fire is not a cropland fire. Damage to crops from fire are often covered by insurance, and are on land that is not "wild." Wildland or grass fires occur in natural, wild areas. Wildland fires are more likely to occur when conditions are favorable, such as during periods of drought when natural vegetation is drier and more combustible.

B. Previous Occurrences

According to the National Interagency Fire Center, not counting prescribed fires, there were 859 wildfires spanning 20,440 acres in the recent five years from 2018 to 2022 in Iowa. The year 2018 accounted for nearly 45% of those fires (and 39% of the acres burned). The wildfires and resultant acres burned of the last five years is only about a third of that of the previous five year period (2013-2017, which 2438 fires and 69,583 acres burned). Going back further in history, between 2002 and 2012 (inclusive) Iowa experienced 1,817 wildfires spanning 33,122 acres and 1,884 prescribed fires spanning 14,079 acres. No event reported in the state has been a historically-significant wildfire, at least compared to the wildfires experienced in western states. Most of the fires in Iowa have been limited to one county. There have been episodes, however, when fire events occurred in multiple counties on the same day. For example, in 2011 fires raged in multiple counties in Iowa. In September of that year numerous wildfires broke out in four counties in northwest Iowa (Buena Vista, Clay, Dickinson, and O'Brien counties). In October 2011 numerous wildfires were reported in five counties in northwest Iowa (Buena Vista, Lyon, O'Brien, Osceola and Sioux counties).[118] The map below shows locations of wildfires that have occurred in Iowa from March 2014 through January 2023.

[117] See Chapter 10 of *National Risk Index Technical Documentation*, November 2021.
[118] Source: NCEI Storm Events Database.

National Interagency Fire Center Reported Fires, March 2014- January 2022.[119]



Compared to other states, Iowa ranked 34th in percent of land in the state burned by wildfire over the period 2013-2021[120]. Over the period 2002-2012, Iowa ranked 44th in number of acres burned by wildfire[121].

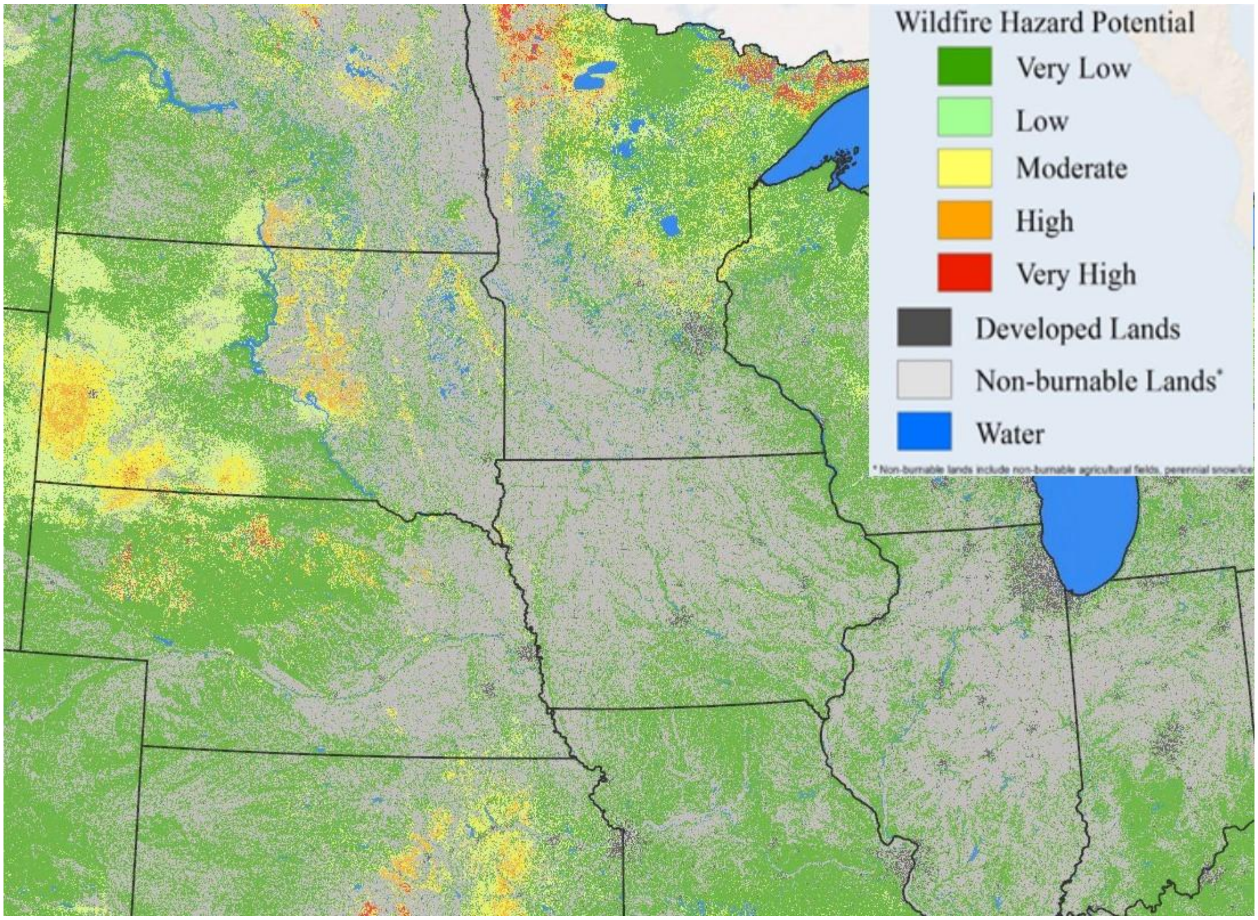
C. Location, Probability and Intensity

The USDA Forest Service's Fire Modeling Institute has developed Wildfire Hazard Potential (WHP) maps for the nation. The 2020 version of their map for Iowa and surrounding states is below. The objective of the WHP map is to:

> depict the relative potential for wildfire that would be difficult for suppression resources to contain…. Areas mapped with higher WHP values … represent fuels with a higher probability of experiencing torching, crowning, and other forms of extreme fire behavior under conducive weather conditions, based primarily on landscape conditions at the end of 2014. On its own, WHP is not an explicit map of wildfire threat or risk, but when paired with spatial data depicting

[119] Retrieved from https://datacentral.press-citizen.com/wildfire-history/?page=1&query=Iowa&anc=active#ftbl March 2023, limited to Iowa.
[120] Data source: National Interagency Fire Center, accessed from https://www.iii.org/table-archive/23284, accessed March 10, 2023. Analysis by Iowa HSEMD.
[121] https://www.firescience.org/worst-states-fire-danger/. Accessed March 10, 2023.

highly valued resources and assets it can approximate relative wildfire risk to those resources and assets.[122]



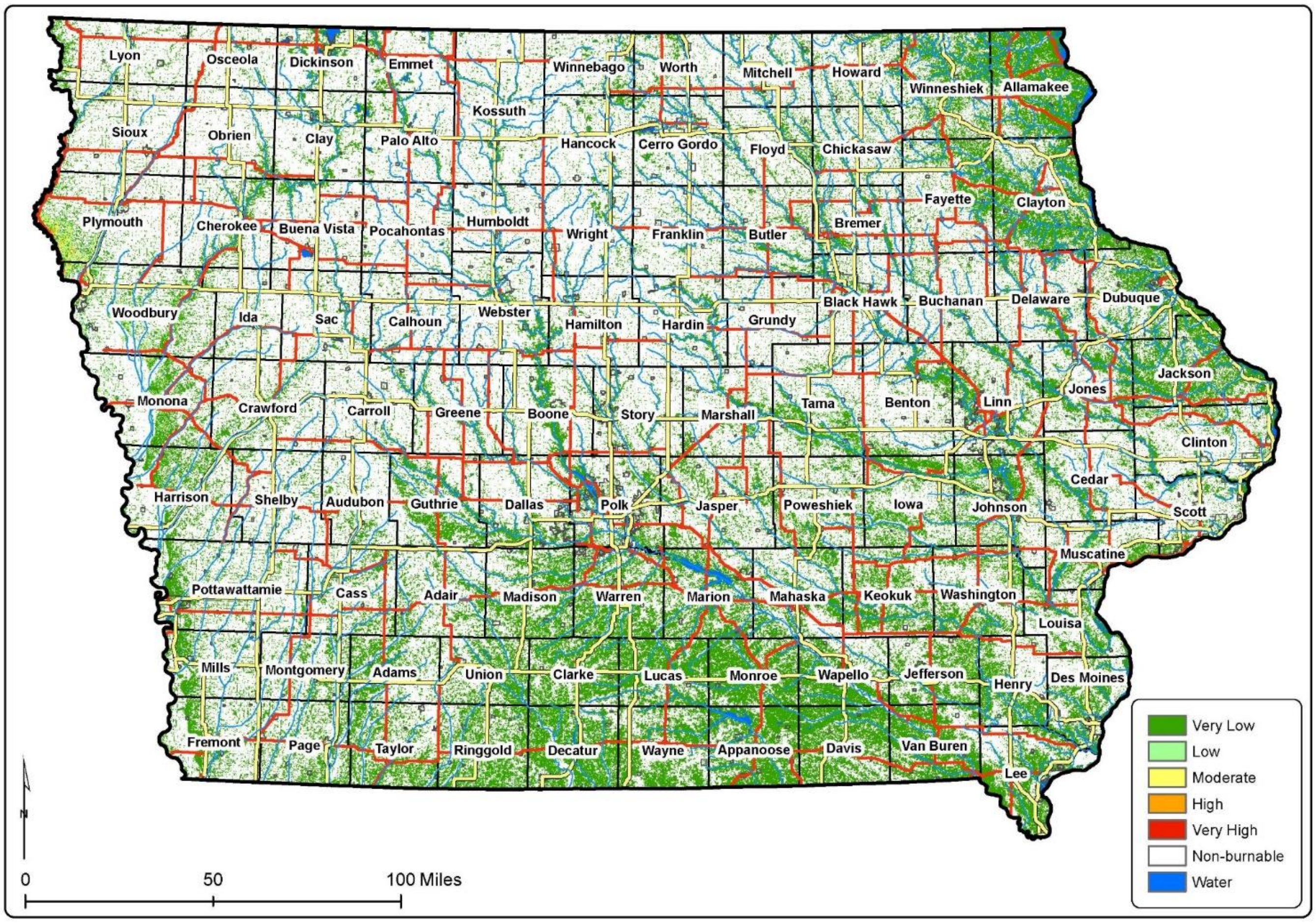
In other words, the WHP does not illustrate what is vulnerable to wildfire, just the locations where wildfire is most likely, or probable, to occur. As can be seen in the WHP map, Iowa has relatively few locations that have much potential for wildfire. Most of the area in the state is considered "Non-burnable Lands" (which includes agricultural fields). Almost the entire rest of the state is mapped with a "Very Low" wildfire hazard potential. In other words, these areas have fuels with a very low "probability of experiencing torching, crowning or other forms of extreme fire behavior". The map also illustrates that whenever wildfires occur in Iowa, they are of little extent, as there is no area for a fire to spread in extent or severity because there is no area which has fuel likely to burn with torching, crowning or other extreme fire behavior.

While the map above shows Iowa at a small-scale, such scale is needed to be able to show several other states and thus illustrate just how little wildfire hazard potential Iowa has compared to other states – only Illinois is similar of all the states. The map below shows the same information but just for Iowa and slightly enlarged to show more detail. Upon very close examination one might be able to see that Plymouth County in northwest Iowa has some area (about 5000 acres) with moderate wildfire potential. To the south of Plymouth County, Woodbury County and Monona County also have some such area (about 1600 acres and 300 acres respectively). These three counties also have the most acres of land rated with moderate wildfire hazard potential, having between 4400 and 15,000 acres each. One other county, Jefferson, has over 1000

[122] https://www.firelab.org/project/wildfire-hazard-potential. Accessed March 10, 2023

such acres (1423 acres). Sixteen counties have between 100 and 800 acres. Thirteen have between 15 and 75 acres, and the rest of the counties in Iowa have no land rated with a moderate wildfire hazard potential or higher.

Wildfire Hazard Potential in Iowa (Version 2020)



D. Summary of Vulnerability

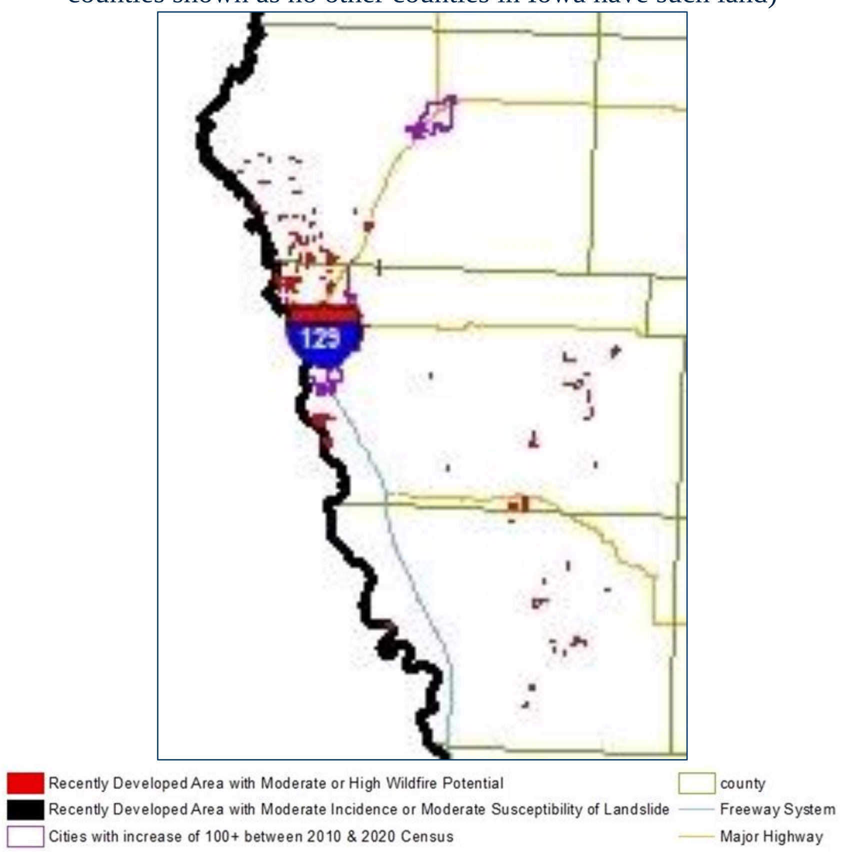
Iowa and Illinois have the smallest percentage of wild land in all of the United States. Consequently, there is simply less opportunity for wildfires in Iowa than most any other state. The land use map in section 1.4 also bears this out, as it shows area mostly covered in crops. The area in Iowa with the most “wild land” is south central and close to the Mississippi in northeast Iowa. Even in those areas the wildfire potential, as shown in the map above, is very low.

The 10 Counties in Iowa with Highest # of Acres with Moderate or High Wildfire Hazard Potential (WHP)		
County	**High WHP Acres**	**Moderate WHP Acres**
Plymouth	5,026	14,970
Woodbury	1,639	7,458
Monona	342	4,449
Jefferson	0	1,423
Decatur	36	793
Harrison	18	576
Ringgold	0	522
Johnson	0	468
Madison	0	378
Union	0	324

As mentioned above, Plymouth County, Woodbury County and Monona County have some acreage rated as having high wildfire hazard potential. Only two other counties have any such acres, and the amounts are quite small: Decatur County has 36 such acres and Harrison 18. The adjacent chart shows the ten counties with the most acreage rated with wildfire hazard potential of "Moderate" or above. According to the analysis by the Fire Modeling Institute, these are the counties that are most vulnerable to wildfire in Iowa. Certain areas in Plymouth, Woodbury and Monona counties may becoming even more vulnerable to damage because they have recent development[123] in areas of moderate or greater wildfire hazard potential (see map below).

FEMA's National Risk Index completed a different analysis that reveals which areas may be most vulnerable based on the Expected Annual Loss (EAL) from wildfire. The NRI analysis also shows Plymouth and Woodbury Counties as most vulnerable to wildfire, according to the EAL figures. Plymouth County's EAL is $115,377 and Woodbury's is $229,725. Polk County, which has the highest property value exposure in the state, comes in a distant third place; its wildfire EAL is less than a third that of Plymouth County's. The Wildfire EAL for the entire state, inclusive of all counties, is $854,539 (as of December 2022, per the FEMA NRI at https://hazards.fema.gov/nri/map).

Recently Developed Iowa Land in Areas with Higher Potential for Wildfire (only Plymouth, Woodbury and Monona counties shown as no other counties in Iowa have such land)



[123] By comparing what land is currently labeled "developed" on the USDA CDL as opposed to what was "developed" ten or twelve years ago, we ascertain the areas that have recently been developed. The map shows land in red that has recently changed from undeveloped (in 2010 CDL) to developed (in 2022 CDL), and also is in an area with higher potential for wildfire.

E. Summary of Problem and Identification of Possible Actions to Mitigate Problem

The Wildfire Preparedness Resource Guide for the Northeast Region (which includes Iowa) states:

> More homes are at risk from wildfire as residential development continues to encroach on forest and wildland areas. Across the majority of states, debris burning is the most frequent human cause of wildfires. These human-caused fires can be prevented and the excessive cost of fire suppression reduced. The first step in wildfire prevention education is to raise awareness of the responsibilities of living in a fire prone environment. Individual and community action can ensure that homes and neighborhoods are prepared for wildfire.

A key action for mitigating wildfire impacts is to educate and make citizens in fire-prone areas aware of what they can and must do to ensure they are adequately prepared for the threat of wildfire. The Iowa DNR supports and encourages involvement in the Firewise Communities Program which has such education and awareness resources. These resources can continue to be made available to the most vulnerable jurisdictions and the property owners there that need them the most.

Vulnerable jurisdictions could also develop or update a Community Wildfire Protection Plan (CWPP) with the involvement of local fire departments, state and local forestry, land managers, community leaders, and the public. The planning process maps assets at risk, and requires actions to reduce risk, such as prescribed burning, fuel reduction, or other measures that adapt a community to better confront their wildfire threat. More details about the CWPP, the Firewise Communities Program and other resources and ideas for wildfire mitigation may be found in the Wildfire Preparedness Resource Guide available through Iowa DNR's Fire Protection and Prevention website (https://www.iowadnr.gov/Conservation/Forestry/Fire-Prevention/Fire-Protection-Prevention#Iowa-Wildland-Fire-Report-Forms-36).

In developing CWPPs or plans to mitigate wildfire, community leaders could consult wildland urban interface maps and information available at http://silvis.forest.wisc.edu/maps/wui. To avoid future risk, local leaders of communities with the most wildfire hazard potential/probability could also consider adopting building and land use codes to limit and/or guide development in areas that would interface with areas with wildfire hazard potential or ensure that adequate safeguards are provided for development (like dry hydrants) in those areas.

3.3.11. Sinkholes

A. General Description

A sinkhole is the loss of surface elevation due to the removal of subsurface support. Sinkholes range from broad, regional lowering of the land surface to abrupt localized collapse. The primary causes of most subsidence are human activities such as underground mining of coal, groundwater/petroleum withdrawal, or drainage of organic soils. Sinkholes can aggravate flooding potential, and collapse of an abandoned mine may destroy buildings, roads, and utilities.

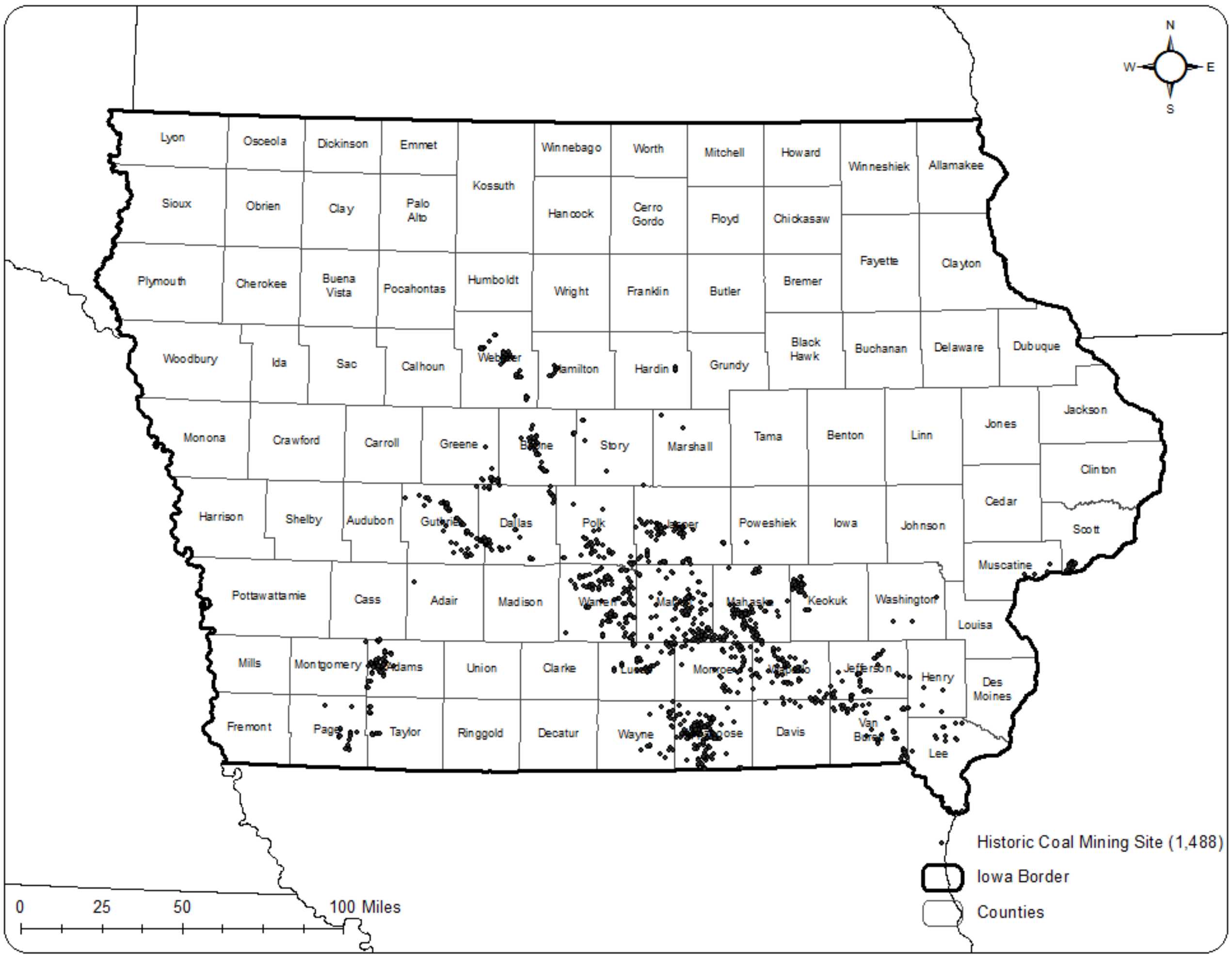
Sinkholes often are found among karst landscapes. The Iowa Geological Survey (IGS) provides this description of karst:

> Karst refers to geologic, hydrologic, and landscape features associated with the dissolution of soluble rocks, such as carbonates and evaporites. . . . [S]inkholes . . . form when the land surface collapses into subsurface voids formed in the slowly dissolving rock. In Iowa, carbonate rocks form the uppermost bedrock over roughly the eastern half of the state, and are mantled with a variable thickness of glacial and other unconsolidated materials. Where these unconsolidated materials are less than 50 feet, and particularly less than 25 feet thick, sinkholes may occur. There are three areas in Iowa where large numbers of sinkholes exist: (1) within the outcrop belt of the Ordovician Galena

> Group carbonates in Allamakee, Clayton, and Winneshiek counties; (2) in Devonian carbonates in Bremer, Butler, Chickasaw, and particularly Floyd and Mitchell counties; and (3) along the erosional edge of Silurian carbonates in Dubuque and Clayton counties. [124]

Sinkholes may also form in old mining locations, which are shown in this map.

Historical Coal Mine Locations, 2017. Source: https://programs.iowadnr.gov/maps//coalmines/# (DNR)



B. Previous Occurrences

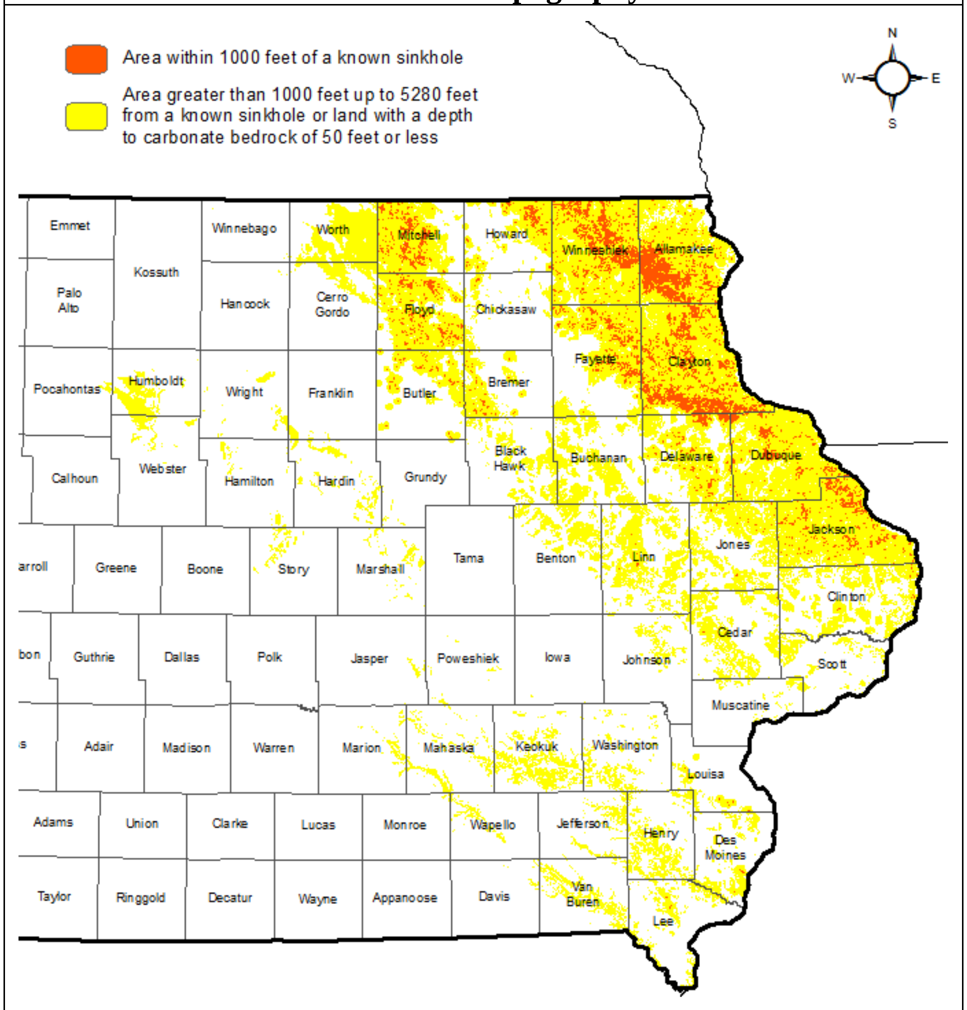
In April 2022 a sinkhole was discovered behind a shopping center at 42nd Street and University in Des Moines when a concrete resurfacing machine fell through the concrete. The sinkhole was 10 foot deep and exposed the foundation of the building and a storm sewer. Six year before, in April 2016, a sinkhole swallowed a 40-foot tree and the front yard of a home in south Des Moines. The sinkhole in front of the home was likely influenced by abandoned coal mines, as it appears the South Des Moines Coal Company operated a 203-acre mine in the area where the sinkhole formed. A map in a 1989 Iowa DNR technical paper[125] shows that the mine was one of several that operated in the Des Moines area during the late 19th and early 20th centuries. More than 200 mines were in the vicinity. In June 2013 a 10-foot-wide and 10-

[124] https://iowageologicalsurvey.org/hazards/ accessed March 10, 2023.
[125] Iowa Department of Natural Resources (1989). *Abandoned Underground Coal Mines of Des Moines, Iowa and Vicinity*, (Plate I). http://s-iihr34.iihr.uiowa.edu/publications/uploads/Tp-08.pdf. Accessed May 11, 2018.

foot-deep hole opened up in a yard in Runnells. The mayor of Runnells also said he had a 20-foot-wide sinkhole in his yard. Just as in south Des Moines and throughout areas of central Iowa, a network of underground coal mines can be found in Runnells.

These describe a few of the sinkholes that have developed in central Iowa in the last decade. Several sinkholes have opened up in other parts of the state in that time, but there is no state or national tracking of sinkhole occurrences and their associated damages to identify exactly when, where or how many. At one time in the past, the Iowa DNR did compile an inventory and mapped sinkhole locations as they existed at that moment in time. That information is presented in the adjoining map (which also shows areas of karst topography where sinkholes are likely to form).

Known Sinkholes and Karst Topography. Source: Iowa DNR



C. Location, Probability, and Intensity

The above map, showing known previous mining areas, also shows areas more probable for sinkholes, because such abandoned mines are areas where sinkholes are more likely to develop. The map showing sinkholes and karst topography also shows areas where there is a higher probability for sinkholes to appear.

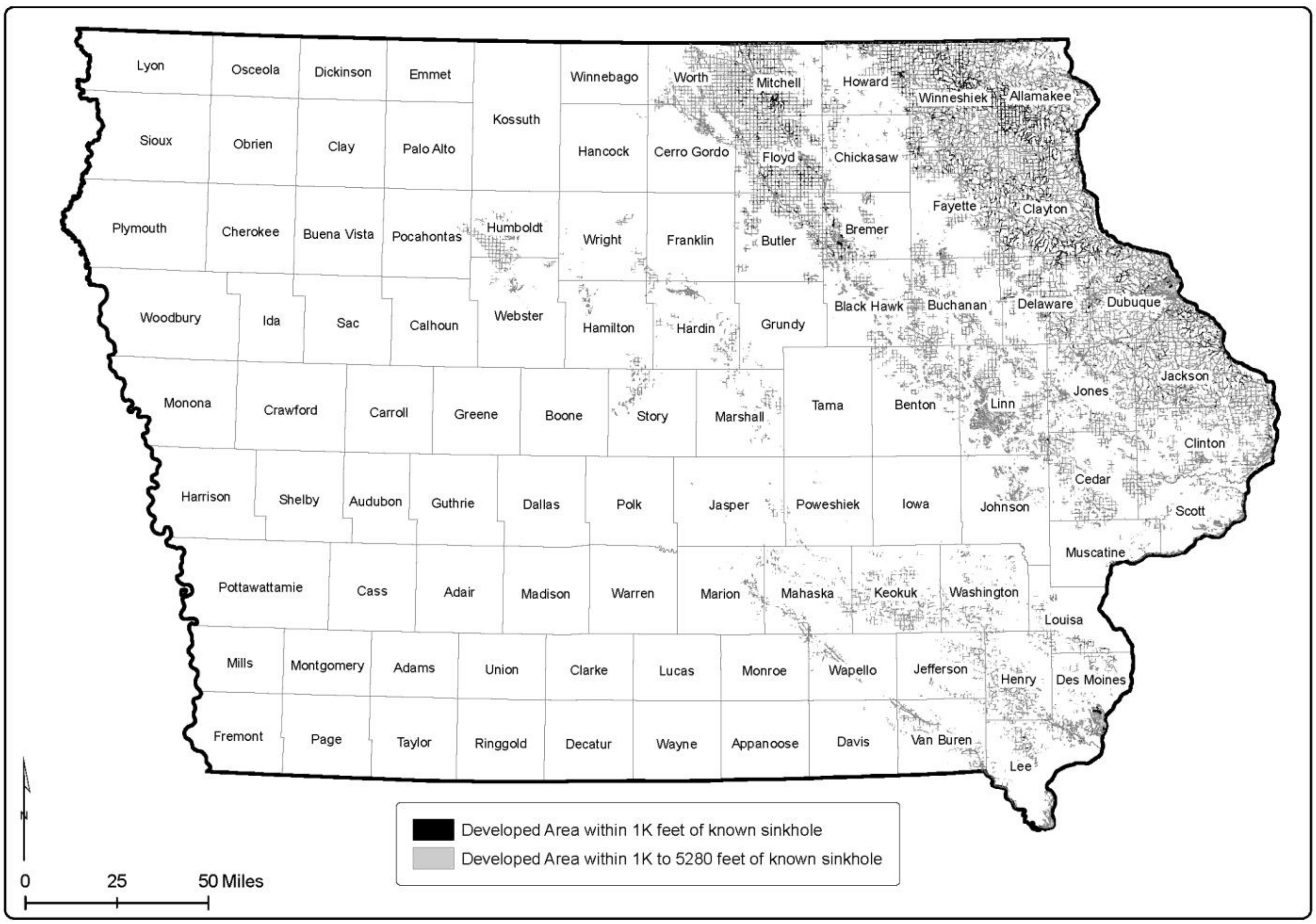
While the mapped mine locations do indicate some abandoned mines, there are other areas not mapped where sinkholes could occur. The IGS estimates as many as 6,000 underground coal mines, mostly in locations now forgotten, are scattered across 38 counties. These could possibly affect up to 80,000 acres of Iowa land. However, DNR officials say that despite the widespread prevalence of abandoned coal mines, they seldom create sinkholes. According to the IDALS Bureau of Mines and Minerals, two or three mine-related sinkholes typically occur each year in Iowa.

D. Summary of Vulnerability and Problem, and Identification of Possible Actions to Mitigate Problem

The two maps above begin to illustrate which counties and jurisdictions would be most vulnerable to sinkholes. The next maps take the information illustrated above and overlay it with where land is developed (as shown in USDA's CDL). By overlaying this geographic data, one can see where developed areas are most vulnerable to sinkhole formation and potential costly damage.

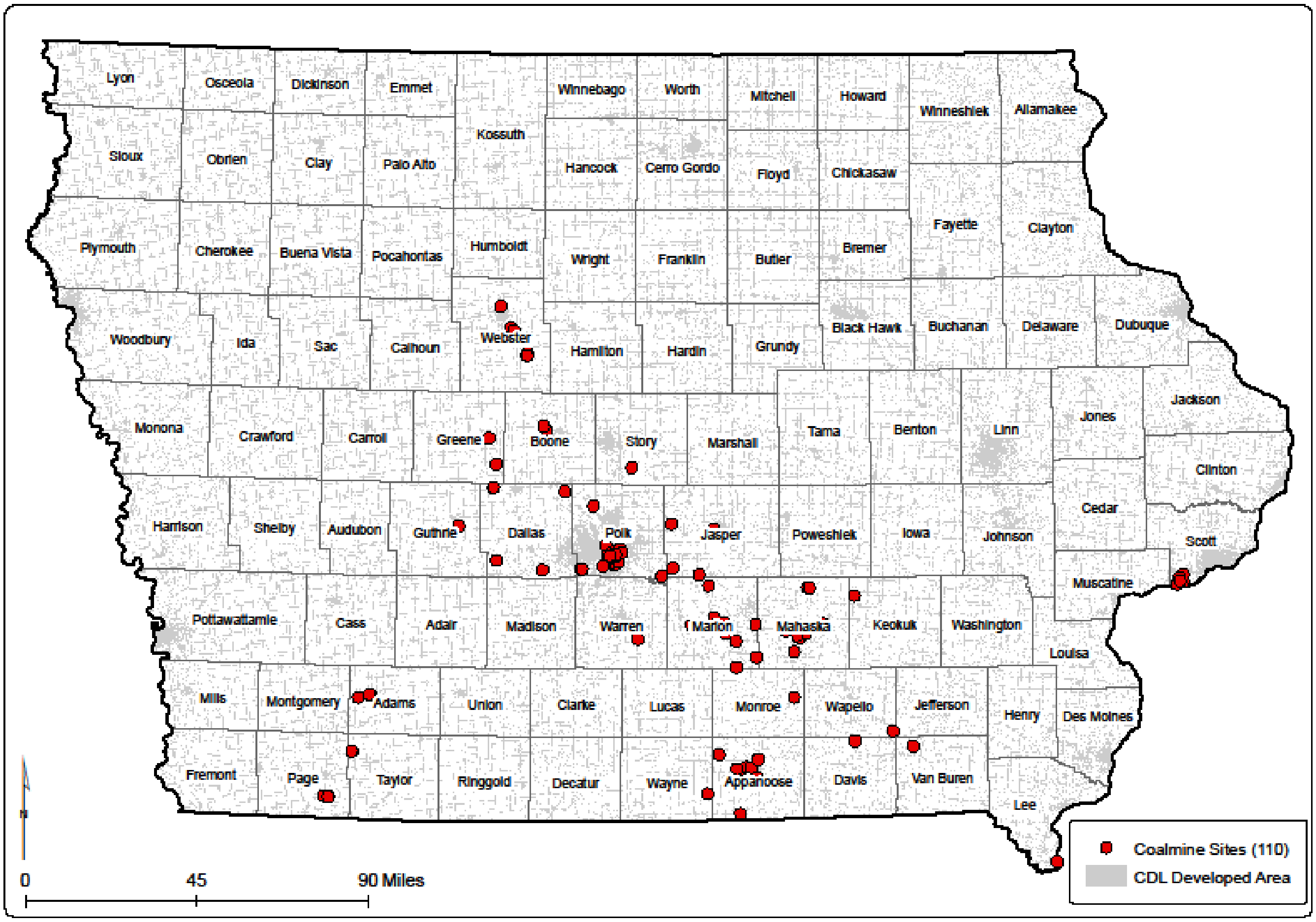
In northeast Iowa the sinkhole threat is due to karst topography, where many sinkholes have already appeared. The three counties in the northeast corner of Iowa (Allamakee, Clayton and Winneshiek) each have over 4500 acres of developed land within 1000 feet of a known sinkhole. The following counties, all in northeast Iowa, have over 12,000 acres of developed land within 1 mile of a known sinkhole in karst topography: Allamakee, Clayton, Clinton, Delaware, Dubuque, Fayette, Floyd, Jackson, Linn, Mitchell, and Winneshiek. The accompanying map shows where developed area is within a mile of a known sinkhole.

Developed Land in Areas of Karst Topography

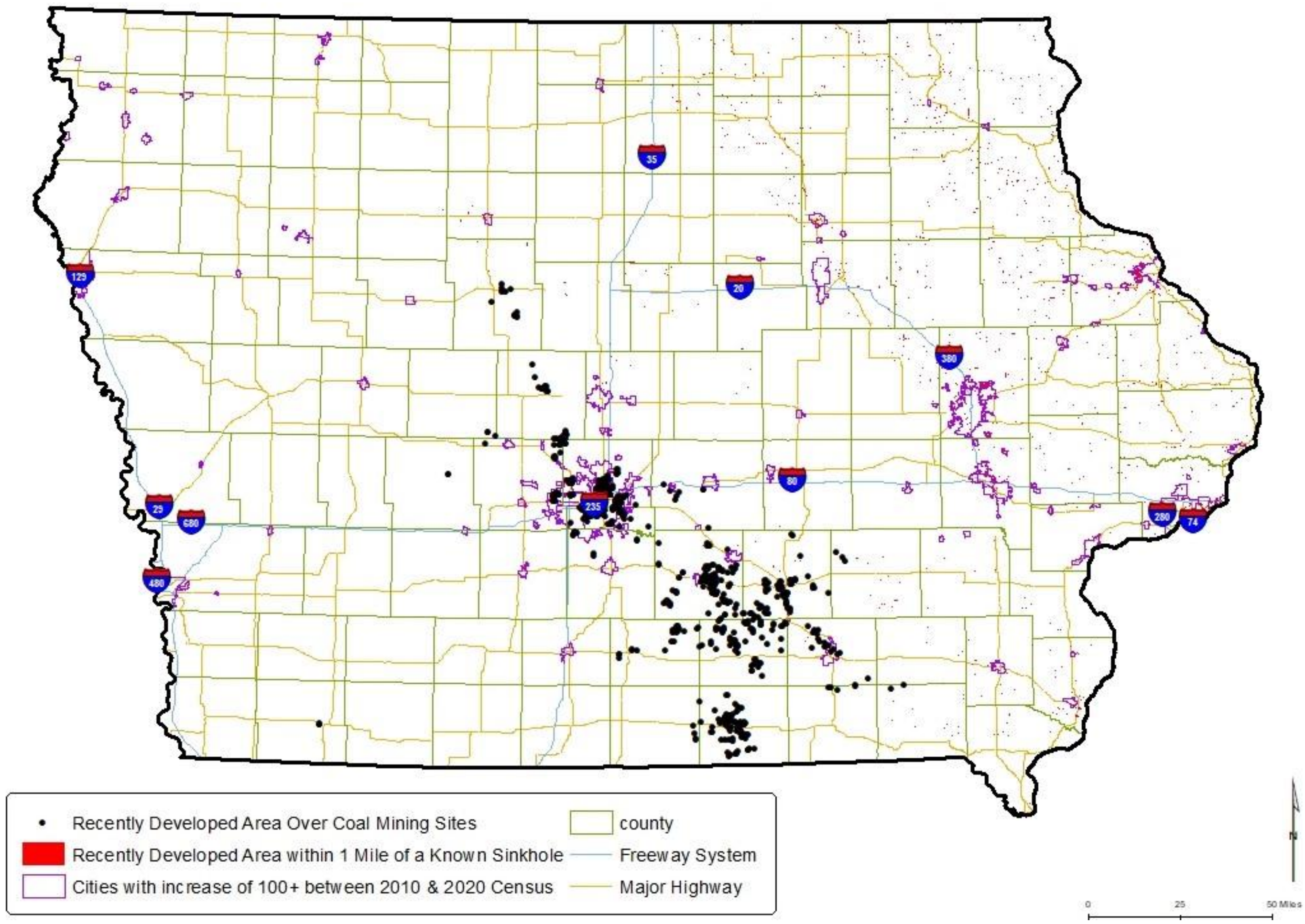


While the sinkhole threat in northeast Iowa is due to karst topography, the threat in central and southern Iowa is due to abandoned mines. In central and southern Iowa, the counties most vulnerable to damage from sinkholes are Appanoose County, Marion County, Mahaska County, and Polk County, the state's largest urban area. These counties have much developed area above abandoned mines, as shown on the accompanying map. Other counties with developed area above several abandoned mines include Webster, Greene, Dallas, Jasper and Scott counties.

Developed Area Vulnerable to Sinkhole Formation Due to Historic Coal Mining Sites Underneath



The next map shows where land has recently been developed within areas at threat of sinkhole formation, whether it be karst topography or abandoned mines.



For all the hazards profiled prior to this one, estimates of either expected annual loss or past average annual loss were provided for counties. Unfortunately, at this time there is not enough data to estimate county or jurisdictional annual loss due to sinkholes, caused either by old mines or by karst. The maps above give some indication of where the threat may be greater. But, those maps do not necessarily show a complete picture. For instance, the locations of all mines are not known and mapped. More information is needed on location and other factors that determine threat.

On April 14, 2016 *The Des Moines Register* reported that a geologist with the Iowa Geological Survey (IGS) said that collapsing mines are typically the culprit with sinkholes in central Iowa. When mine shafts are covered by firm bedrock, mine shaft cave-ins have little impact on the surface. But, if shafts are closer to the surface with inadequate bedrock above and mines are relying on old support beams, then the deterioration and failure of such beams can result in a sinkhole at the surface that causes problems. According to the IGS geologist, there is no reason for panic, but abandoned mines are an important consideration for residents and developers. One action for mitigating the potential problems with sinkholes would be to identify and map existing sinkholes and evaluate the potential for new sinkholes.

3.3.12. Expansive Soils

A. General Description

Soils and soft rock that tend to swell or shrink excessively due to changes in moisture content are commonly known as expansive soils, although they may also be referred to as "shrink-swell soils", "swelling clay soils", or similar names. The more water such soils absorb, the more their volume increases. Expansions of ten percent or more are not uncommon. This change in volume can exert enough force on a building or other structure to cause damage. Expansive soils will also shrink when they dry out. This shrinkage can remove support from buildings or other structures and result in damaging subsidence. Fissures in the soil can also develop. These fissures can facilitate the deep penetration of water when moist conditions or runoff occurs. This cycle of shrinkage and swelling places repetitive stress on structures, and damage worsens over time[126]. The effects of expansive soils are most prevalent in regions that typically have moderate to high precipitation, with effects especially felt at times when prolonged periods of drought are followed by long periods of rainfall. The hazard occurs in many parts of the southern, central, and western United States. Estimates conducted in 1980 put the annual damage from expansive soils as high as $7 billion, with single-family and commercial buildings accounting for nearly one-third of the total damage amount. (Krohn and Slosson, 1980). However, because the hazard develops gradually and seldom presents a threat to life, expansive soils have received limited attention, despite their costly effects. Expansive soils can also contribute to or cause damage to roadways, bridges, pipelines, and other infrastructure.

The availability of data on expansive soils varies greatly. In or near metropolitan areas and at dam sites, abundant information on the amount of clay generally is available. However, for large areas of the United States, little information is reported other than field observations of the physical characteristics of clay.

B. Previous Occurrences

There have been no recorded incidences of disaster associated specifically to expansive soils.

C. Location, Probability, and Intensity

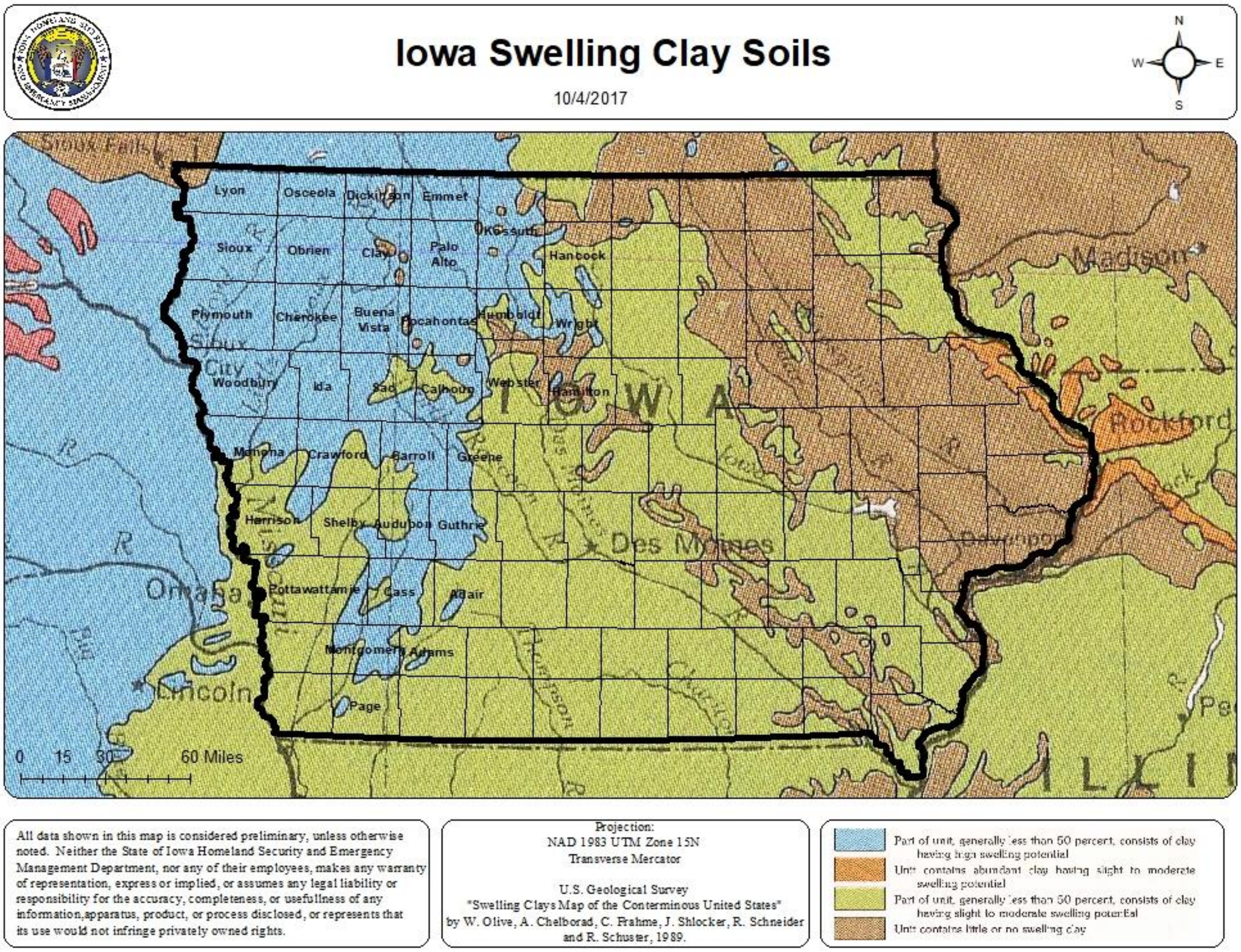
Probability and frequency analyses have not been prepared because of the nature of occurrence of this hazard. This is consistent with other geologic hazards that occur slowly over time. As such, the duration of response to expansive soils and their associated risk to public property and loss of life is unknown.

According to the U.S. Geological Survey (USGS), the northwest section of the state has the highest probability of the incidence of expansive soils. That risk is rated as "less than 50 percent of the soil being of the expansive clay" variety.

D. Summary of Vulnerability and Problem, and Identification of Possible Actions to Mitigate Problem

The adjoining map depicts the potential swelling clay deposits in Iowa. While maps show that there are areas of the state that may be somewhat susceptible to expansive soils, this is currently not a hazard that has had much impact. At least, impact from this hazard has not attracted enough attention for anyone to keep track of losses due to the hazard.

[126] From https://geology.com/articles/expansive-soil.shtml



So, no comprehensive data is available to compare past losses across the state. Nonetheless, a few communities in areas more susceptible to expansive soils have been experiencing growth and development and are thus at increased risk of future loss. Such communities are in Lyon, Sioux, Woodbury, Monona, and Buena Vista counties. It would be wise for jurisdictions in these areas of higher swelling potential to include in their land use and development codes a requirement to look carefully at the potential for damage from expansive soils at specific sites.

A potential mitigation action would be to require or encourage construction projects to analyze the soil of the building site to identify the types of soil present and determine their expansive properties. It is possible to build successfully and safely on expansive soils if stable moisture content can be maintained or if the building can be insulated from any soil volume change that might occur[127]. If, after testing, the soil is determined to be expansive, building codes could require that designs and methods be utilized to minimize moisture content changes and insulate from soil volume changes.

127 https://geology.com/articles/expansive-soil.shtml

3.4. Other Hazards

This section contains a brief overview of several "non-natural" hazards that affect Iowa, namely:

1. Animal/Crop/Plant Disease
2. Pandemic Human Disease
3. Hazardous Materials
4. Infrastructure Failure
5. Radiological Incident
6. Terrorism
7. Transportation Incident

The first two of these "non-natural" hazards may be considered biological, whereas the remaining five are considered "man-made" hazards (aka human-caused). It is worth noting that, according to FEMA Hazard Mitigation Assistance (HMA) guidance, mitigation projects for mitigating man-made hazards are not eligible for FEMA HMA grant funding.

We are concerned about mitigation efforts for these hazards, but more in-depth analyses of these other hazards (in relation to mitigation) is handled by other agencies: for instance, the Iowa Department of Health and Human Services (IHHS) for pandemic human disease, the Iowa Department of Agriculture and Land Stewardship (IDALS) or the Iowa Department of Natural Resources (DNR) for animal/crop/plant disease, and the Iowa Department of Transportation (DOT) and Iowa Utilities Board (IUB) for infrastructure failure. They have performed extensive discussion and analysis on these hazards for regulatory and preparation purposes. This plan contains a brief presentation on these human-caused and biological hazards primarily to be consistent with the State's Threat and Hazard Identification and Risk Assessment (THIRA). The THIRA contains an examination of State and local capability to respond to twenty different hazards, which includes the 13 natural hazards profiled in the previous section, as well as these 7 man-made and biological hazards discussed briefly below.

3.4.1. Animal/Crop/Plant Disease

An outbreak of disease transmitted from animal to animal or plant to plant represents an animal/crop/plant disease. A disease outbreak will likely have a severe economic implication and/or public health impact well beyond the borders of Iowa. A crop/plant pest infestation will likely have severe economic implications, cause significant production losses, or significant environmental damage. Within the United States (U.S.) and throughout the world there are diseases that can make both livestock and wild animals sick, causing production losses or even death. Some of these diseases are naturally found in the U.S. and are called endemic diseases. Others are not normally found in the U.S. and are called foreign animal diseases.

The introduction of some high-consequence diseases could significantly limit or eliminate our ability to move, slaughter, and export animals and animal products. An outbreak will have wide-spread economic and societal implications for our state, the nation, and potentially the world. Response to and recovery from infectious animal disease outbreaks will be lengthy, and many producers may never be able to return to business. There would also be many indirect effects on our economy. Rumors of an infectious animal disease outbreak could cause significant damage to the markets as was evidenced in a 2003 incident in Kansas where just the rumor of a foot-and-mouth disease outbreak caused the market to plummet. Further evidence of this occurred in the 2009 H1N1 (swine flu) influenza outbreak where lack of understanding about the transmission of the virus caused losses in Iowa's pork markets.

Pest infestations can cause widespread crop/plant loss and resulting economic hardships on farmers, landowners, and related businesses. Once infestation occurs, the pest may become endemic, causing repeated losses in subsequent growing years. Loss of production could affect all related industries including fuel, food, synthetics, processors, etc. Every year the Iowa Department of Agriculture and Land Stewardship conducts numerous animal disease investigations.

With observed and predicted increases in average atmospheric temperature, and the resulting increase in the moisture-holding capacity of the air, the Fourth National Climate Assessment anticipates increased pressure on agriculture from diseases and pests.[128] Increases in extreme weather patterns (namely drought intermingled with excessive heat and extreme precipitation events) can also be expected to increase the likelihood of plant and animal diseases and pests. As plant hardiness zones shift northward due to the warming climate, invasive plant and animal species may become more common in Iowa (e.g., kudzu or brown marmorated stink bugs).

Surface wind speeds (standard measurement height of 32 feet) over Iowa declined from the 1980s until about 2010, which provides less crop ventilation and more heat stress for plants and animals. However, this trend has since reversed and global surface wind speeds have instead increased in the past decade. The future of wind speed trends is uncertain. Reduced winds would create favorable conditions for survival and spread of unwanted weeds, fungi, pests, and pathogens. Waterlogged soil conditions during early plant growth often result in shallower root systems that are more prone to disease, nutrient deficiencies, and drought stress later in the season. In 2010 wet soil conditions are cited as cause for the epidemic of soybean sudden death syndrome that occurred that year. Other crop diseases and pests (such as Asian soybean rust) have not been observed in Iowa as of yet, but if warming winter trends persist they could expand their ranges to include Iowa.

In 2015, Iowa experienced significant impacts to our avian populations when highly pathogenic avian influenza (HPAI) affected 77 sites in Iowa in 18 counties across the state. The more than 33 million affected birds had to be euthanized and disposed of, the facilities had to be sanitized, and the stocks replaced once assurances were made that the disease would not recur. The direct economic impact of replacing the affected birds was in excess of $83.6 million. This figure does not include unemployment during the timeframe of the disaster nor the cost of euthanizing and disposal of the carcasses.

Some measures that may be taken to mitigate disease among animals include

- Safe feeding practices
- Preventive health care for animals
- Educating the public and employees working in industries raising and processing food
- Encouraging reporting of potential disease outbreaks
- Limiting exposure of animals to vectors (e.g., insects), wildlife, visitors, or potentially contaminated vehicles
- Cleaning and disinfection
- Removal of and separation from dead animals or animal waste
- Creating plans for preventing infectious diseases (for individuals)
- Creating plans for responding to infectious disease outbreaks (for governments)

[128] NCA4, Chapter 21: Midwest, “Agriculture”, https://nca2018.globalchange.gov/chapter/21/

To this end, IDALS has developed plans and strategies for responding to foreign animal diseases, modeled after FEMA's Emergency Support Functions. These include controlling movements, emergency vaccination programs, training for veterinarians, etc.

3.4.2. Pandemic Human Disease

Pandemic human disease has long been a known threat, but it was catapulted to the forefront of public thought in 2020 as the multi-year, COVID-19 pandemic caused by the novel SARS-COV2 virus swept across the globe, causing massive disruptions to public health and healthcare systems, public life and society, and economies at every scale. The reverberations from this pandemic are ongoing.

An incident related to human disease is defined as a medical, health, or sanitation threat to the public, including contamination, epidemics, plagues, or infestations. Public health action to control infectious diseases in the 21st century is based on the 19th century discovery of microorganisms as the cause of many serious diseases (e.g., cholera and tuberculosis). Disease control resulted from improvements in sanitation and hygiene, the discovery of antibiotics, and the implementation of universal childhood vaccination programs. Scientific and technologic advances played a major role in each of these areas and are the foundation for today's disease surveillance and control systems.

Scientific findings have contributed to a new understanding of the evolving relationship between humans and microbes. There are 67 infectious diseases designated for 2013 as notifiable at the national level. A notifiable infectious disease is one which must be reported to authorities because regular, frequent, and timely information regarding individual cases is considered necessary for the prevention and control of the disease.

The Iowa Department of Health and Human Services tracks epidemiological statistics in Iowa. Public health agencies work to protect Iowans from infectious diseases and preserve the health and safety of Iowans through disease surveillance, investigation of suspected outbreaks, education, and consultation to county, local, and health agencies. Public health agencies also work to reduce the impact of communicable diseases in Iowa and to eliminate the morbidity associated with these diseases. Programs guide community-based prevention planning, monitor current infectious disease trends, prevent transmission of infectious diseases, provide early detection and treatment for infected persons, and ensure access to health care for refugees in Iowa. Iowans remain vulnerable to diseases known and unknown even though vaccines exist for many modern diseases.

A pandemic human disease is one that is prevalent over a whole country, region, continent, or world. Many diseases throughout the history of the world have been pandemic. The 1918 influenza pandemic killed an estimated 50 million people. More than 25 percent of United States population was afflicted and in one calendar year average life expectancy dropped by 12 years. Influenza pandemics in 1957 and 1968 killed 70,000 and 34,000 people respectively worldwide. The H1N1 pandemic flu may have killed as many as 18,000 people in 2009-2010. A pandemic will have widespread economic and societal implications for our state. Response to and recovery from a pandemic will likely be lengthy if Iowa is severely infected. The death rate of a pandemic depends on the number of people infected, the virulence of the virus, characteristics and vulnerability of the population, and availability and effectiveness of preventative measures. Response to future pandemics will depend on the severity of the pandemic.

The COVID-19 pandemic, which began in China in 2019 and was declared an emergency in the United States in early 2020, killed over 10,700 people in Iowa by March of 2023, according to the CDC. The pandemic led to unprecedented levels of quarantining and social distancing, causing massive disruptions to the U.S. economy and society. Response to the pandemic varied by state and local jurisdiction, with some issuing "stay at home" orders, limiting large gatherings; closing schools, daycares, bars, and restaurants; mandating mask usage (and eventually vaccines). Others went in the opposite direction, even going so far as to ban mask or vaccine mandates. The CDC reported an age-adjusted death rate in Iowa of 76 deaths per 100,000 people for the year 2021, which is relatively low on the national scale, but higher than all neighboring states except Missouri. With billions of dollars invested and with extraordinary international cooperation, vaccines against the novel virus were developed within a year of the pandemic's onset. One study estimates vaccines saved 14 to 20 million lives from COVID-19 worldwide,[129] while another study estimated three million lives saved in the U.S. alone.[130]

There have been annual outbreaks of influenza that have affected Iowans. IHHS reports show that the peak impact of the various strains of the flu occur from January through March with an occasional occurrence from August through October. The Zika virus affected one person in 2017 and 26 people in 2016. None of the affected females were pregnant. Half of the affected persons had traveled to the Caribbean.

Similar to animal and plant diseases, the observed and projected trend toward higher temperatures and humidity in Iowa is expected to increase the likelihood of epidemic diseases.[131] Some insects carrying viruses not normally seen in the U.S. are likely to find a more hospitable climate, including ticks carrying Lyme disease or mosquitoes carrying West Nile, chikungunya, dengue, yellow fever, and Zika viruses. These are changes likely to impact southern states before Iowa, but traveling Iowans would be exposed, and the possibility of such insects in Iowa nonetheless increases.

Additionally, pathogens that thrive in warmer waters, currently affecting primarily southern states, may find Iowa lakes and waterways more hospitable as well. For instance, the "brain-eating amoeba", Naegleria fowleri, infected and killed a swimmer in Lake of Three Fires in southern Iowa in 2022. This was Iowa's first case of this amoeba infecting a human. This particular pathogen is not likely to reach the level of a pandemic, given that the most affected states, Texas and Florida, have had less than one case annually on average. It illustrates, however, the effect that a warming climate can have on the proliferation of other disease-causing organisms.

After losing over 10,000 Iowans and seeing over a million positive test results, the state has likely made it through the worst of the COVID-19 pandemic, but the virus is now endemic, and other novel viruses may come into contact with humans in the future. Mitigating the effects of the next pandemic is something the state can and should consider now.

3.4.3. Hazardous Materials

This hazard encompasses fixed hazardous materials, pipeline transportation, and transportation of hazardous materials. This can include the accidental release of flammable or combustible, explosive, toxic, noxious, corrosive, oxidizable, irritant, or radioactive substances or mixtures that can pose a risk to life, health, or property, possibly requiring evacuation. Chemicals are manufactured and used in ever-increasing types and

[129] https://www.thelancet.com/journals/laninf/article/PIIS1473-3099(22)00320-6/fulltext
[130] https://www.commonwealthfund.org/blog/2022/two-years-covid-vaccines-prevented-millions-deaths-hospitalizations
[131] NCA4, Chapter 14: Human Health, https://nca2018.globalchange.gov/chapter/14/

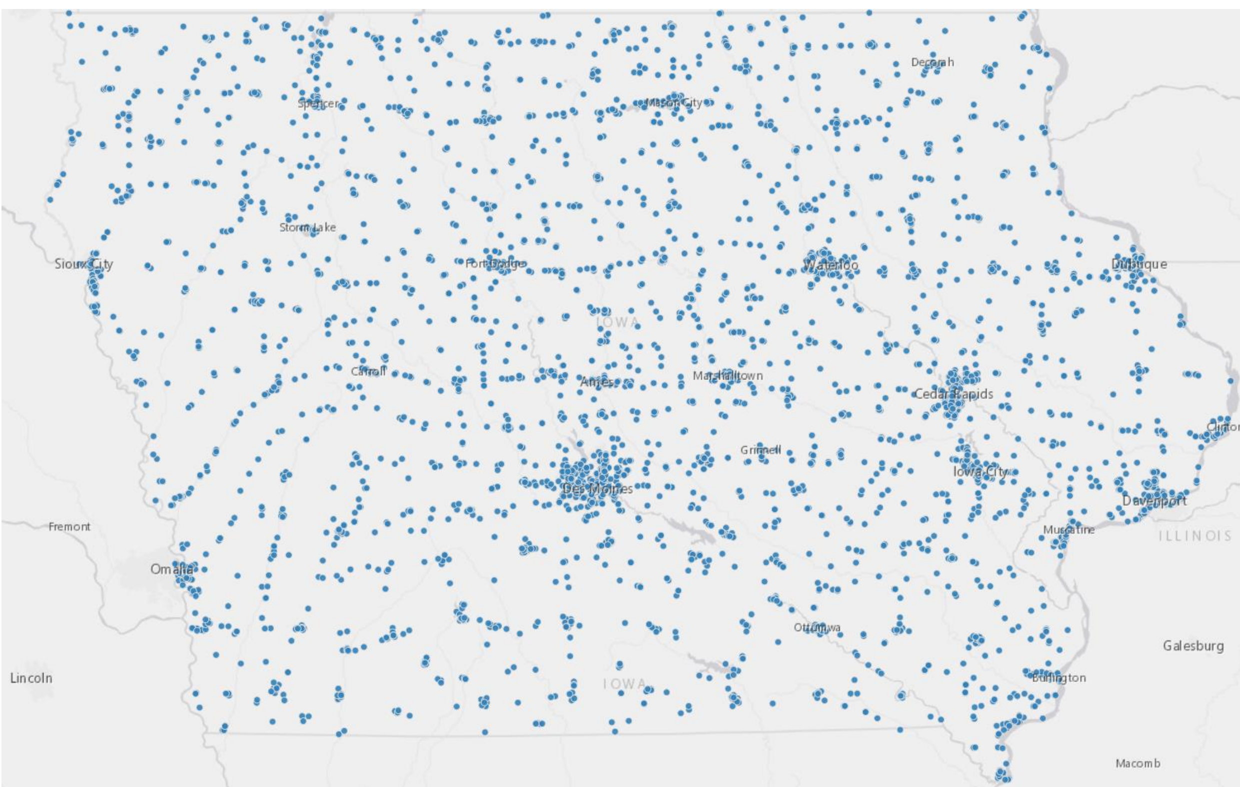
quantities and as many as 500,000 products pose physical or health hazards and can be defined as hazardous chemicals.

A fixed hazardous materials incident is the accidental release of chemical substances or mixtures which presents a danger to the public health or safety during production or handling at a fixed facility. Fixed hazardous materials incidents usually affect a localized area, and the use of planning and zoning can minimize the area of impact.

While safeguards are increasing, more and more potentially-hazardous materials are being used in commercial, agricultural, and domestic activities. This situation is further complicated by the density of people and hazardous materials in Iowa.

During the period of January 2018 through May 2023, a total of 2,906 hazardous materials spills were reported to the Iowa DNR (see https://programs.iowadnr.gov/hazardousspills/Introductory.aspx). During this time, fixed facilities also experienced 3,089 incidents according to the Iowa DNR. Fixed facility releases accounted for 58.5 percent of total releases.

Facilities that have a material safety data sheet (SDS) for any hazardous chemical stored or used in the work place above regulatory thresholds must submit an emergency and hazardous chemical inventory form (Tier Two) to the DNR, local emergency planning committee (LEPC), and local fire department. There are approximately 4,600 sites in Iowa that, because of the volume or toxicity of the materials on site, are designated as Tier Two facilities under the federal Superfund Amendments and Reauthorization Act. They are scattered throughout Iowa, as illustrated in the adjoining map.



Map of Tier II Chemical Storage Facilities (https://geodata.iowa.gov/datasets/iowadnr::chemical-storage-facilities-tier-ii/explore)

Facilities must provide an emergency notification and a written follow-up notice to the LEPC and the

Iowa DNR if there is a release into the environment of a hazardous substance that is equal to or exceeds the minimum reportable quantity set in the regulations.

According to Iowa DNR's Hazardous Material Release Database[132], 3,131 releases of hazardous materials occurred between January 2018 and May 2023. Of these, 38 resulted in evacuations, 38 resulted in fatalities, and 24 resulted in fish kills. A total of 127 releases had injury potential. Such releases occurred in all 99 counties, with Polk County and Mills County having the most releases. The most common type of material released was diesel fuel, followed by anhydrous ammonia and then gasoline.

Building awareness of the potential hazardous materials in a community is a good first step to mitigating a hazardous materials incident. The Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA) establishes requirements for Federal, State, local governments, Indian Tribes, and industry regarding emergency planning and "Community Right-to-Know" reporting on hazardous and toxic chemicals. The act requires the establishment of a State Emergency Response Commission (SERC) and Local Emergency Planning Committees (LEPCs). In Iowa the SERC is made up of the Iowa Department of Homeland Security & Emergency Management (HSEMD) and the Iowa Department of Natural Resources (DNR). EPCRA provisions help increase the public's knowledge and access to information on chemicals stored at individual facilities, their uses, and releases into the environment. States and communities, working with facilities, can use the information to improve chemical safety and protect public health and the environment.

You can find what facilities are located in your neighborhood from the US EPA website, EnviroFacts or the state of Iowa's website, Facility Explorer.

The emergency planning section of the EPCRA is designed to help communities prepare for and respond to emergencies involving hazardous substances. Every community in the United States must be part of a comprehensive plan. Per EPCRA requirements, every county updates its Hazardous Materials emergency plan every year.

3.4.4. Infrastructure Failure

This hazard encompasses a variety of occurrences, including communication failure, energy failure, structural failure, and structural fire. This includes an extended interruption, widespread breakdown, or collapse (part or all), of any public or private infrastructure, that threatens life and property. Potential causes of infrastructure failure include severe weather, space weather/solar flare, excessive use, poor maintenance, poor design or construction, or supply chain issues, among others.

Communication failure is the widespread breakdown or disruption of normal communication capabilities. Telephone service, local government radio facilities, electronic broadcast services, emergency 911, law enforcement, fire, emergency medical services, public works, and emergency warning systems are just a few of the vital services that rely on communication systems to effectively protect citizens. Business and industry rely heavily on various communication media as well. Mechanical failure, traffic accidents, power failure, line severance, solar flares, and severe weather can affect communication systems and disrupt service. Disruptions and failures can range from localized and temporary to widespread and long term. If switching stations are affected, the outage could be more widespread.

[132] https://programs.iowadnr.gov/hazardousspills/Reports/Ad-Hoc-Report.aspx

An extended interruption of electric, petroleum, or natural gas service, by an actual or impending acute shortage of usable energy, could create a potential health problem for the population and possibly even mass panic.

International events could potentially affect supplies of energy-producing products while local conditions could affect distribution of electricity, petroleum, or natural gas. The magnitude and frequency of energy shortages are associated with international markets. Local and state events such as ice storms can disrupt transportation and distribution systems. If disruptions are long-lasting, public shelters may need to be activated to provide shelter from extreme cold or extreme heat. Stockpiles of energy products eliminate short disruptions but can increase the level of risk to the safety of people and property near the storage sites.

The energy crisis of the 1970s had significant impact on many consumers in Iowa. High inflation and unemployment were associated with the excessive dependence on foreign oil during the early and mid-1970s. An energy shortage of that magnitude has not affected Iowa in recent years. State and federal government strategies exist to respond to energy shortages, but are generally called upon only when free market forces are unable to provide for the health, welfare, and safety of citizens. The State of Iowa has multiple strategies to limit the likelihood of an energy shortage and keep energy supply and demand in check. These strategies include:

- voluntary and mandatory demand reduction mechanisms
- substitution of alternative energy sources when possible
- state government programs to curtail excessive use

The federal government has a strategic petroleum reserve to supplement the fuel supply during energy emergencies. Shortages, especially electrical shortages, can be unpredictable and have immediate effects. Natural events, human destruction, price escalation, and national security energy emergencies can cause unavoidable energy shortages.

The collapse (partial or total) of any structure including roads, bridges, towers, and buildings is considered a structural failure. A road, bridge, or building may collapse due to the failure of the structural components or because the structure was overloaded. The age of the structure is sometimes independent of the cause of the failure. Enforcement of building codes can better guarantee that structures are designed to hold up under normal conditions. Routine inspection of older structures may alert inspectors to weak points. The level of damage and severity of the failure is dependent on factors such as the size of the building or bridge, the number of occupants of the building, the time of day, day of week, amount of traffic on the road or bridge, and the type and amount of products stored in the structure. There have been structural failures across the state in the past as mentioned above. They have included homes, commercial structures, and communications towers. There is no central collection point for this information, but news articles document infrastructure failure.

Civil structures may fail for a variety of reasons. The unprecedented growth in technology has resulted in a host of problems related to complex structures, special materials, and severe operational and environmental loads. These include fire, excessive vibrations, explosion, and high-energy piping failures. With some possible exceptions (misuse, accidental or environmental loads), the causes of failure may be found in deficiencies of design, detailing, material, workmanship, or inspection. With the aging structures in the country and problems with new materials discussed above, structural failures will continue to occur. Efforts to inspect and maintain these structures will lessen the probability of failure, but not guarantee that it will not occur. Internal weaknesses can be hidden from inspectors and may not be realized until it is too late.

No major widespread communication failures have occurred in Iowa. Local incidents, due to weather conditions, equipment failure, excavation incidents, or traffic accidents have been reported, but the outages were usually resolved in a timely manner. One notable exception is the derecho that swept across the state in August of 2020. Some areas in eastern Iowa were without power for over a week, and with widespread debris limiting road access, restoration of communications, fuel supply, and electricity was significantly delayed.

A. Waterways

The 2021 American Society of Engineers Report Card for America's Infrastructure graded the inland waterway system as a D+, reflecting the age, condition, and reliability of the infrastructure. The system relies primarily on public investment and has suffered from chronic underfunding. Many of the country's locks and dams have reached or even far exceeded design life, resulting in infrastructure deteriorating faster than it is being replaced. With grain exports increasing and the expansion of the Panama Canal expected to shift the amount of goods that can be shipped to Asia via ports on the Gulf of Mexico, Iowa has a sincere interest in the condition of its inland waterway infrastructure.

The locks and dams bordering Iowa are undersized for modern Upper Mississippi tow lengths and are hindered by unexpected repairs. The average age of these 11 locks and dams is over 80 years, 30 years past the design life. Only one lock bordering Iowa is long enough to accommodate a modern 1,200-foot barge tow. The remaining 10 are 600 feet long, which means barge operators must split the tow in half, lock through multiple times, and resecure the barges together before continuing. This creates major delays and congestion at each lock and dam, generating a ripple effect of longer delays. The average delay at the locks along Iowa's border is almost 3 hours, and has generally been increasing over the past decade.

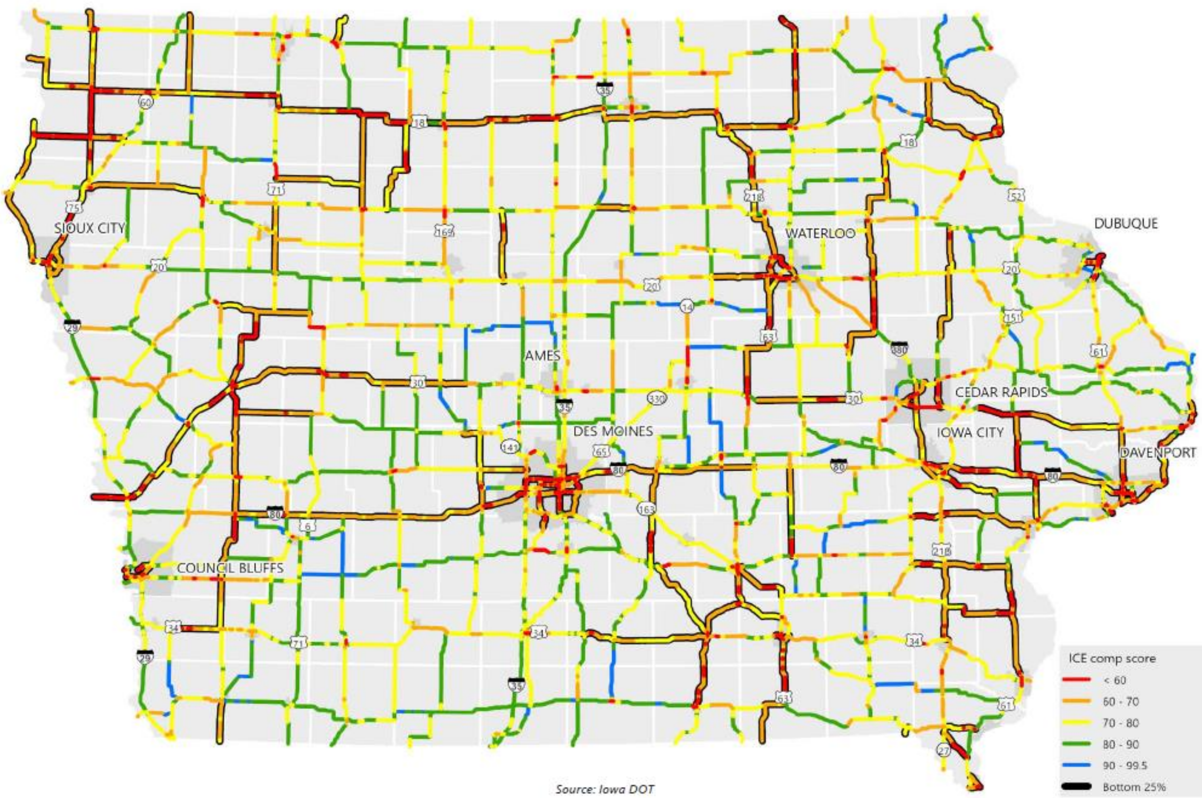
Also contributing to delay times is lock unavailability, both scheduled and unscheduled. Due to the age and condition of the infrastructure, locks and dams must often be closed for maintenance and repairs. On average, unscheduled repairs account for more than 50 percent of lock closures. Delays, congestion, and unavailability due to closures are significant threats to efficient goods movement.

Given the condition, size, and average delay of the 11 locks bordering Iowa, all are considered freight bottlenecks. It is clear that a lack of repairs, maintenance, and modernization will continue to have a negative impact on the efficiency and condition of the infrastructure. Failure or closure of a lock could be catastrophic for the region. The USACE has identified over $948 million in deferred/backlog maintenance and major rehabilitation and repair costs for the 11 locks and dams bordering Iowa. Addressing these needs is essential to ensure continued viability of the Mississippi River for transporting freight to and from Iowa. (See IDOT's *Iowa in Motion 2050* for more information.)

B. Roads

In 2014, Iowa DOT developed the Infrastructure Condition Evaluation (ICE) tool to evaluate the state's Primary Highway System with a single composite rating. Figure 5.10 (as numbered in *Iowa in Motion 2050*) below shows the segment-level ICE output, and highlights the bottom 25 percent of primary highway corridors based on the ICE analysis.

Figure 5.10: ICE composite ratings and bottom 25 percent of Primary Highway System corridors – statewide view



Source: Iowa DOT

The ICE composite ratings are recalculated each year and available through an annual report and interactive website, enabling the tracking of roadway conditions at segment, corridor, and system levels. The core goal of ICE is to serve as an initial screening and prioritization tool to assist the Iowa DOT in identifying areas that should be considered for further study, though it does not identify specific projects or alternatives that could be directly considered as part of the programming process.

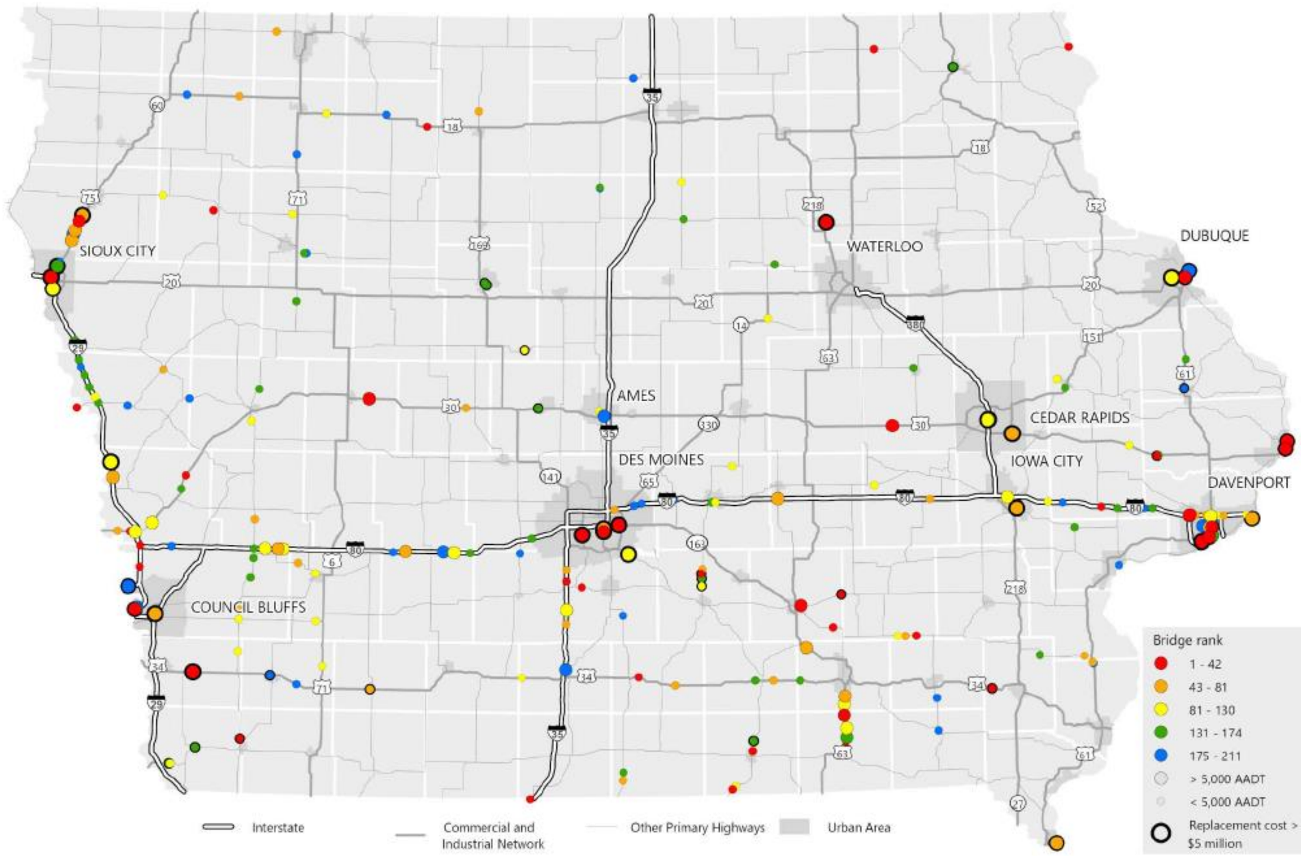
C. Bridges[133]

Similar to roadway conditions, DOT calculates bridge conditions by combining multiple factors to obtain an index value that is indicative of a structure's overall condition/sufficiency. These factors include structural condition, load carrying capacity, horizontal and vertical clearances, width, traffic levels, type of roadway served, and the length of out-of-distance travel if the bridge were closed. Reductions for specific vulnerabilities are also factored into the rating.

Figure 5.12 (as numbered in *Iowa in Motion 2050*) shows the bridges identified as the bottom five percent of Iowa DOT's owned and maintained structures, including two specific sub-categories: structures with an estimated replacement cost of more than $5 million, and structures on routes of over versus under 5,000 annual average daily traffic (AADT). (More information in *Iowa in Motion 2050.)*

[133] Information and some language taken from ASCE's *2023 Iowa Report Card for Infrastructure* and Iowa DOT's *Iowa in Motion 2050*.

Figure 5.12: Bottom 5 percent of Primary Highway System bridges – statewide view



Source: Iowa DOT

The Iowa Section of the ASCE, in its *2023 Iowa Report Card for Infrastructure* provides an overview of the condition of Iowa's bridges. It states that the condition of a bridge is the physical ability of the structure to carry design loads. Bridges are considered structurally deficient if significant load-carrying elements are found to be in poor or worse condition due to deterioration and/or damage. A structurally deficient bridge does not necessarily imply it is unsafe or in danger of imminent collapse. As of 2018, structurally deficient and poor are used interchangeably.

	State Owned	County Owned	City Owned	Total
Good	2,011	6,783	510	9,304
Fair	2,154	7,216	526	9,896
Poor	30	4,366	203	4,599
Total	4,195	18,365	1,239	23,799

In Iowa, just under 20% – 4,599 of the total bridges – are in poor condition. Iowa is first in the nation for the number of poor bridges within its state boundaries. Based on the individual bridge, poor bridges are kept open without restriction, posted for a maximum allowable vehicle weight, restricted by lane or number of vehicles, or closed. Iowa's poor bridges are primarily located on low-volume facilities. The average daily traffic on these poor bridges is 147 vehicles per day, and the median ADT value is less than 35 vehicles per day.

D. Drinking Water[134]

The visible components – wells, pumps, intakes, plants, towers, and controls – of the water production process are generally well maintained but are aging and will require significant reinvestment in the future. Typical water systems such as wells, pumps, and treatment facilities have a 20-year expected useful life before requiring major rehabilitation or replacement. Many communities have exceeded the life of these components and they must invest in major rehabilitation or replacement projects. The network of distribution piping in the state varies widely in age. Rural water systems are relatively new in Iowa and generally have distribution systems that are less than 50 years old. Municipal water systems report that greater than 50% of their distribution system is greater than 50 years old, with some systems having pipes exceeding 100 years old. Water main breaks can force temporary boil orders if the break causes a loss of system pressure. Substantial portions of the distribution lines in systems are becoming old enough to cause concern about future reliability. The generally accepted life of pipe is between 80 years to 100 years, depending on material type and other environmental conditions. Therefore, communities should be investing between 1% to 3% of the value of their distribution system to replace their aging buried infrastructure. Few, if any utilities are currently reinvesting in their systems at that rate.

Many of Iowa's treatment facilities are more than 50 years old and while they may be in fair condition, these aging facilities demand more preventative and reactive maintenance to keep them operational. Similar to the distribution systems, many of these facilities are aging and will require significant rehabilitation in coming years.

Since the Flint, Michigan water crisis began in 2014, lead and copper pipes have become more of a focus for water utilities in Iowa. In January 2021, the EPA issued the Lead and Copper Rule Revisions. This rule is intended to find more sources of lead in drinking water and to complete more lead service line replacements in communities. As a result of this rule, utilities are working to complete an inventory of service line materials by October 16, 2024. The number of lead service lines in Iowa is presently unknown. Completing these service line inventories will provide data on how many service lines of various types exist in the state and where property owners or utilities will need to replace these lead service lines. The 2021 Infrastructure Investment and Jobs Act, also known as the Bipartisan Infrastructure Law, included approximately $15 billion for lead service line removal and replacement across the country, of which Iowa received $44.9 million in FY 2022.

The majority of Iowa public water supplies (PWS) are meeting the core purpose of protecting public health. No waterborne diseases or deaths were reported from Iowa public water supply systems in 2021. Over 2.94 million people served by Iowa's PWS regularly received water from systems meeting all health-based drinking water standards. Of the 1,842 regulated public water supplies, 96.2% met all health-based standards, and the number of violations are trending downward.

E. Energy

1. Capacity

Generally, electricity is generated from coal, natural gas, wind, or other resources at a centralized power plant. High-voltage electricity then travels through interconnected transmission lines, before reaching

[134] Information and some language taken from ASCE's *2023 Iowa Report Card for Infrastructure*.

substations, where the electricity is "stepped down" to a lower voltage. Distribution lines then take the lower voltage electricity to consumers. In Iowa, coal and natural gas are all imported, with natural gas moving by pipelines and coal primarily by rail. Natural gas-fired power plants contributed 9% of Iowa's in-state generation in 2021, and as of 2021, the only nuclear plant in Iowa is permanently closed. The state's remaining electricity is generated from a combination of hydropower, solar, biomass, and petroleum.

Since 2008, Iowa has generated more electricity each year than the state has consumed. This means that excess power generated in Iowa is sold to other utilities and sent over the electric grid to other states. Ian Dobson, an engineering professor at Iowa State University, describes how "electricity is made and consumed at the same time. Thus, the energy put into the grid must equal the energy pulled from it, especially with the lack of storage within the system."

Historically, the grid relies on the burning of fossil fuels to generate power, and the amount of power generated can be adjusted based on the demand for energy. But the generation of solar and wind energy fluctuates, and can cause massive strain on a system that relies on a constant balance. As the regional grid operator, MISO is tasked with making sure the right amount of electricity is generated across its various zones. That energy can then be sold and transmitted between its member utilities that distribute the power to their customers.

Local distribution grids, which are estimated to contain 10 times the line mileage of the transmission grid connecting them, are unquestionably the weakest part of our electric delivery structure. Nationally, 92% of outages occur on the distribution network. To improve reliability, one trend that is taking hold in Iowa is to bury distribution lines underground. Burying lines underground has numerous advantages, including increased resiliency against weather, temperature shifts, and sabotage. However, line burying is very expensive and not always appropriate, especially in areas prone to flooding.

2. ***Resilience.***

If consumers need more electricity than baseload power plants can provide, operators respond by increasing production from centralized generation facilities that are already operating at a lower level or on standby, importing electricity from distant sources, or calling on end-users who agreed to consume less electricity from the grid through demand response programs. This becomes of the utmost importance during times of natural disasters that impact energy transmission and delivery. Resiliency during extreme weather events should be a top priority for policymakers. In Iowa, aging energy infrastructure is the main cause of power losses to homes and businesses, and storms exacerbate challenges associated with aging transmission and distribution infrastructure. In fact, 90% of outages across the US are caused by weather related events. Iowa saw this firsthand during recent storm events like the August 2020 derecho. In the derecho's aftermath, roughly 250,000 residents were without power. A resilient and reliable power grid can help protect residents and businesses from extreme weather, which starts with a much stronger transmission system. Dusky Terry, President of ITC Midwest, noted that "The widespread power outages caused by last summer's devastating derecho in Iowa and the recent extended sub-freezing temperatures across much of the US demonstrate the importance of a resilient and reliable electric power grid. Continued investments in transmission are essential to ensure older transmission lines are rebuilt to provide greater system resiliency and reliability during extreme weather events". Eric Larson, Climate Central's Senior Scientist of Energy Systems, has noted that Iowa, "… needs a much beefier transmission system, not only beefier in terms of resilience against climate change impacts, but also much larger than we have now…."

F. Rail

The Iowa State Rail Plan (2021) and Iowa State Freight Plan (2022) include detailed lists of railroad choke points. The causes of these choke points include track congestion, operational issues, insufficient track capacity due to size and weight restrictions, flood-prone areas, and a lack of transload accommodations. The industry standard for rail car weight is 286,000 pounds (including the weight of the freight and the rail car). The diminished capacity of these lines can decrease the efficiency of moving local freight, such as food products, chemicals, and farm products. Several upcoming transload projects for improving the loading and unloading of rail cars will increase the efficiency of freight moving on the rail network.

Passenger rail in Iowa has had little change in recent years, with only two long-distance Amtrak lines running through the state. Six passenger depots board an average of 60,000 passengers each year. A Chicago to Iowa City passenger rail line has been awarded federal funding. Implementation will be split into two phases: Chicago to the Quad Cities and the Quad Cities to Iowa City. The line is expected to carry 300,000 passengers annually with two daily trips traveling at 79 miles per hour. This line is expected to eventually be extended to Omaha, with speeds reaching 110 mph.

The increased ton-miles of freight moving across the Iowa rail network have required an increased investment in maintenance and improvement of rail infrastructure. In 2019, $166.7 million was spent on maintenance and improvements, with over $1 billion being spent in the past five years. In 2021, Iowa railroad companies totaled $2.4 billion in revenue, marking the highest revenue total Iowa has ever seen for railroads. This mark is part of a continued trend since the 1990s and includes recovery from a dip due to the COVID-19 pandemic. Track rail inspectors have been able to identify areas in need of maintenance. Inspection and safer conditions and operations have led to safer railroads across the state.

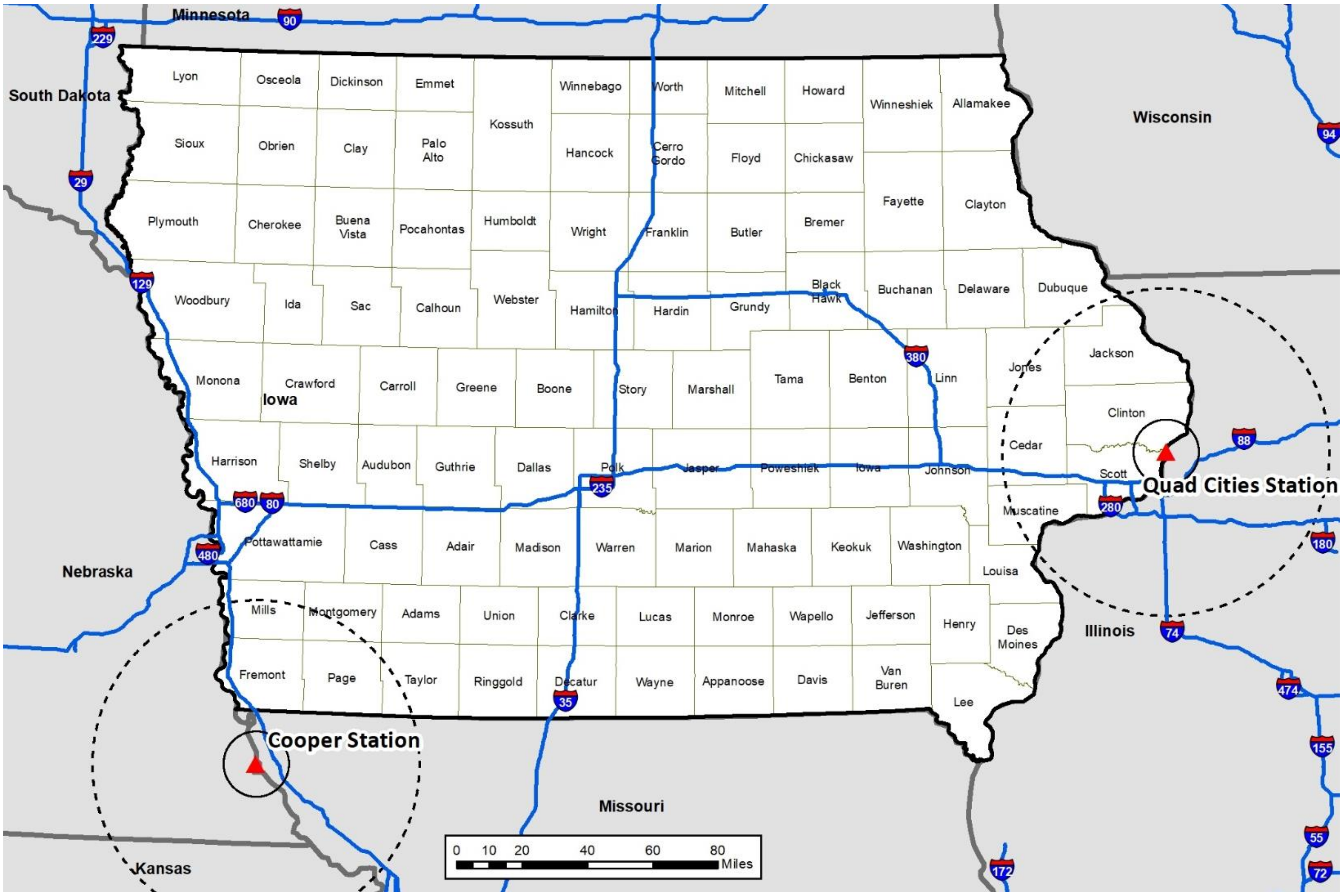
3.4.5. Radiological

A radiological incident is an occurrence resulting in a release of radiological material at a fixed facility or in transit. An incident resulting in a release of radiological material at a fixed facility includes, but is not limited to, power plants, hospitals, and laboratories. Although the term "nuclear accident" has no strict technical definition, it generally refers to events involving the release of significant levels of radiation. Most commercial nuclear facilities in the United States were developed in the mid-1960s and are designed to withstand aircraft attack. With this level of design they should withstand most natural hazards, but events that occurred in 2011 at the Fukushima nuclear plant in Japan illustrate the possibilities of what can happen in a worst-case scenario. The Japanese plant may have been able to withstand either the earthquake or the tsunami, but both hazards together caused release of radioactive materials.

There are two nuclear power plants that operate close to Iowa's borders; the Quad Cities Generating Station near Cordova, Illinois, and the Cooper Nuclear Station near Brownsville, Nebraska. The map below identifies the location of each facility as well as the 10-mile and 50-mile planning buffers.

These plants are required by the U.S. Nuclear Regulatory Commission to support local and state preparedness activity and are required to hold full-scale exercises that involve state agencies every other year. Nuclear power plants in the U.S. are also required to have both an onsite and offsite emergency response plan as a condition of obtaining and maintaining a license to operate that plant. Onsite emergency response plans are approved by the **Nuclear Regulatory Commission (NRC)**. Offsite plans (which are closely coordinated with the utility's onsite emergency response plan) are evaluated by the **Federal Emergency Management Agency (FEMA)** and provided to the NRC, who must consider the FEMA findings when issuing or maintaining a license.

Nuclear Power Plants Impacting Iowa (2021). Source: Iowa HSEMD



Although construction and operation of nuclear power plants are closely monitored and regulated by the NRC, an accident, though unlikely, is possible. The potential danger from an accident at a nuclear power plant is exposure to radiation. This exposure could come from the release of radioactive material from the plant into the environment, usually characterized by a plume (cloud-like) formation. The area the radioactive release may affect is determined by the amount released from the plant, wind direction and speed and weather conditions (i.e., rain, snow, etc.) which would quickly drive the radioactive material to the ground, hence causing increased deposition of radionuclides.

Emergency classifications defined by the United States Nuclear Regulatory Commission are divided into four categories. Each calls for a certain level of response from plant and government personnel. From least to most severe, the classifications are:

- Unusual event
- Alert
- Site area emergency
- General emergency

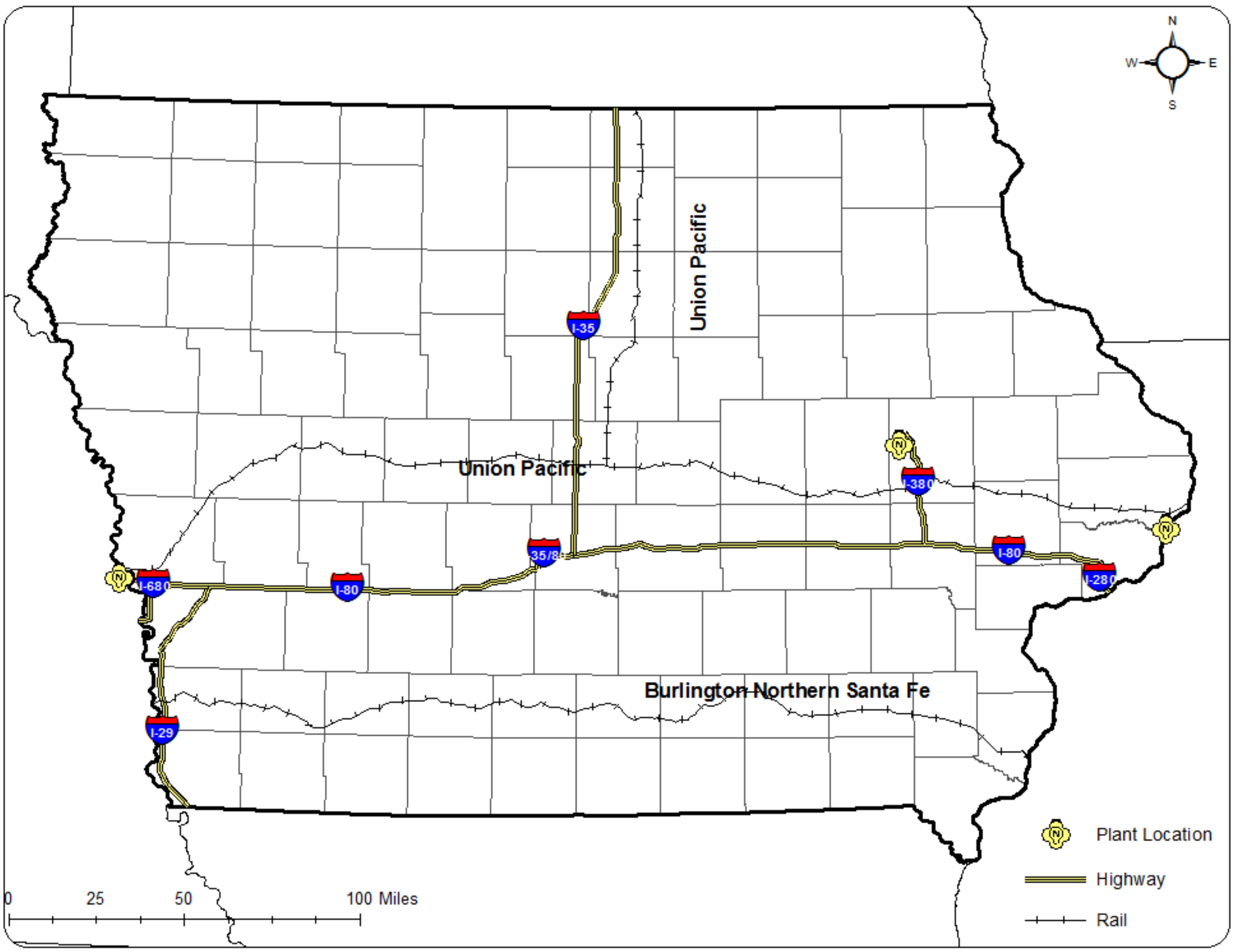
An **unusual event** constitutes events that are in process or have occurred which indicate potential degradation in the level of safety of the plant. No release of radioactive material requiring offsite response or monitoring is expected unless further degradation occurs.

If an **alert** is declared, events are in process or have occurred that involve an actual or potential substantial degradation in the level of safety of the plant. Any releases of radioactive material from the plant are expected to be limited to a small fraction of the U.S. Environmental Protection Agency (EPA) protective action guides (PAG).

A **site area emergency** involves events in process or which have occurred that result in actual or likely major failures of plant functions needed for protection of the public. Any releases of radioactive material are not expected to exceed the EPA PAGs except near the site boundary.

A **general emergency** involves actual or imminent substantial core damage or melting of reactor fuel with the potential for loss of containment integrity. Radioactive releases during a general emergency can reasonably be expected to exceed the EPA PAGs for more than the immediate site area.

Potential Transportation Routes for Nuclear Waste. Source: Nevada Agency for Nuclear Projects



Radiological incidents related to transportation are described as an incident resulting in a release of radioactive material during transit. The transportation of radioactive material by any means of transport is licensed and regulated by the federal government. When these materials are moved across Iowa highways, State officials are notified and appropriate escorts are provided. As a rule there are two categories of radioactive materials that are shipped over the interstate highways.

Low-level waste consists primarily of materials that have been contaminated by low-level radioactive substances, but pose no serious threat except through long-term exposure. These materials are shipped in sealed drums within placarded trailers. The danger to the public is no more than that which exists from other hazardous materials. High-level waste, usually in the form of spent fuel from nuclear plants, is transported in specially constructed casks that are built to withstand a direct hit from a locomotive. Potential rail and highway routes for the shipment of radioactive waste have been identified and mapped above.

Since 1990, hundreds of shipments have been made through Iowa. There have been no occurrences of a radiological incident in Iowa. Transportation accidents are the most common type of incident involving radioactive materials because of the sheer number of radioactive shipments.

3.4.6. Terrorism

This hazard encompasses a wide variety of human-caused threats including enemy attack, biological terrorism, agroterrorism, chemical terrorism, conventional terrorism, cyber terrorism, radiological terrorism, and public disorder. This includes the use of multiple outlets to demonstrate unlawful force, violence, and/or threat against persons or property causing intentional harm for purposes of intimidation, coercion, or ransom in violation of the criminal laws of the United States. These actions may cause massive destruction and/or extensive casualties.

Enemy attack is an incident that would cause massive destruction and extensive casualties. An all-out war would affect the entire population. Some areas would experience direct weapons' effects of blast, heat, and nuclear radiation. Other areas could experience indirect weapons' effects, primarily radioactive fallout.

The federal government monitors the international political and military activities of other nations and would notify the State of Iowa of escalating military threats. There are many small military installations in Iowa; most are Iowa National Guard assets spread throughout the state comprised of various military units and functions. There have been no enemy attacks on or in Iowa in modern times. The only history of enemy attack dates back to the days of settlement and the Civil War in the 1800s. The breakup of the Soviet Union and other Soviet Bloc nations ended the Cold War. An enemy attack is a remote possibility due to international conflicts and the large number of weapons still in existence throughout the world. Although Des Moines is the state capital, a county seat, and Iowa's most populous city, and thus a potential target in an all-out military attack on the United States, it is unlikely the state would be a primary target during a conventional attack.

Mass demonstrations, or direct conflict by large groups of citizens, as in marches, protest rallies, riots, and nonpeaceful strikes, are examples of public disorder. These are groups of people assembling together to substantially interfere with public peace and constitute a threat. Use of unlawful force or violence against another person, causing property damage, or attempting to interfere with, disrupt, or destroy the government, political subdivision, or group of people, are potential methods employed. Labor strikes and work stoppages are not considered in this hazard unless they escalate into a threat to the community. Vandalism is usually initiated by a small number of individuals and limited to a small target group or institution. Most events are within the capacity of local law enforcement.

Large-scale civil disturbances rarely occur, but when they do they are usually an offshoot or result of one or more of the following events: labor disputes where there is a high degree of animosity between the participating parties; high-profile/controversial laws or other governmental actions; resource shortages caused by a catastrophic event; disagreements between special interest groups over a particular issue or cause; or a perceived unjust death or injury to a person held in high esteem or regard by a particular segment of society. There have been numerous labor disputes and protests in Iowa, but these have remained fairly nonviolent. Other nonpeaceful incidents have occurred in the state, but within the response capabilities of local law enforcement.

Although large-scale destructive civil disturbances are rare, the potential is always there for an incident to occur. This is even more true today, where television, radio, and the Internet provide the ability to instantly broadcast information (factual or not) in real time to the entire community. Often times that coverage helps to spread the incident to other, uninvolved or unaffected areas, exacerbating an already difficult situation. This also allows people who are prone to inciting others to engage in violent or unlawful behavior, and previously not involved, to participate in the disturbance for no other reason than to riot, loot, burn, and destruct property. Alcohol is often involved in public disorder, especially related to college campuses, sporting events, and concerts.

Use of biological agents against persons or property in violation of the criminal laws of the United States for purposes of intimidation, coercion, or ransom can be described as biological terrorism. Liquid or solid contaminants can be dispersed using sprayers/aerosol generators or by point-of-line sources such as munitions, covert deposit, and moving sprayers.

Biological agents may pose viable threats from hours to years depending upon the agent and the conditions in which it exists. Depending on the agent used and the effectiveness with which it is deployed, contamination can be spread via wind and water. Infections can be spread via human or animal vectors.

Causing intentional harm to an agricultural product or vandalism of an agricultural/animal related facility is classified as agroterrorism. Activities could include: intentional introduction of disease, animal rights activists who release animals; disgruntled employees who intentionally contaminate bulk milk tanks or poison animals; ecoterrorists who destroy crops/facilities; theft of agricultural products, machinery, or chemicals; or criminals who vandalize agricultural facilities. Depending upon the type of action taken, the implications will vary greatly.

Chemical terrorism involves the use, or threatened use, of chemical agents against persons or property in violation of the criminal laws of the United States for purposes of intimidation, coercion, or ransom. Liquid/aerosol or dry contaminants can be dispersed using sprayers or other aerosol generators, liquids vaporizing from puddles/containers, or munitions. Chemical agents may pose viable threats for hours to weeks depending on the agent and the conditions in which it exists. Contamination can be carried out of the initial target area by persons, vehicles, water, and wind. Chemicals may be corrosive or otherwise damaging over time if not mitigated.

Use of conventional weapons and explosives against persons or property in violation of the criminal laws of the United States for purposes of intimidation, coercion, or ransom is conventional terrorism. Hazard effects are instantaneous; additional secondary devices may be used, lengthening the time duration of the hazard until the attack site is determined to be clear. The extent of damage is determined by the type and quantity of explosive. Effects are generally static other than cascading consequences, incremental structural failures, etc. Conventional terrorism can also include tactical assault or sniping from remote locations.

Iowa has not been immune to acts of terrorism or sabotage. The state has experienced many bomb threats. During the spring of 2002, 18 pipe bombs were found in mailboxes in five states stretching from Illinois to Texas, including Iowa. Six people were injured in the bombings in Iowa and Illinois. In 2005 and 2006, pipe bombs were used in attempted murder cases in two Iowa cities. In 1991 there was a murder suicide at the University of Iowa. Recent national events have increased awareness pertaining to school safety, workplace safety, and vulnerability at public gatherings. Unfortunately, there will never be a way to eliminate all types of these clandestine activities. If someone is inclined to cause death and destruction, they are usually capable of finding a way to carry out their plans. As perpetrators of terrorism improve their ability to collect information, raise money, and issue rhetoric, implementation of effective counter measures becomes even more important.

Electronic attack using one computer system against another in order to intimidate people or disrupt other systems is a cyber attack. For the purposes of delineating the hazard of terrorism, we will not consider as cyber terrorism a cyber crime committed for the sole purpose of financial gain. While cyber crime of that nature is very serious, we are interested in the context of emergency management only the type of terrorist attacks that cause disruption to other sectors, such as electrical or other utilities, or which attacks result in the deployment of rolling response equipment, such as police and fire vehicles. With that definition in mind, cyber terrorism may last from minutes to days depending upon the type of intrusion, disruption, or infection. Inadequate security can facilitate access to critical computer systems, allowing them to be used to conduct attacks. Cybersecurity and critical infrastructure protection are among the most important national security issues facing our country today, and they will only become more challenging in the years to come.

Radiological terrorism is the use of radiological materials against persons or property in violation of the criminal laws of the United States for purposes of intimidation, coercion, or ransom. Radioactive contaminants can be dispersed using sprayers/aerosol generators, or by point-of-line sources such as munitions, covert deposits, and moving sprayers, or by the detonation of a nuclear device underground, at the surface, in the air, or at high altitude.

Iowa has experienced at least one event where subjects broke into a city's water supply and, it was suspected, deposited chemicals. There have been many releases of anhydrous ammonia by persons engaged in clandestine drug manufacturing.

Iowa has not been immune to acts of terrorism or sabotage, as the state has experienced many threats in the past. Most incidents have been limited to reported suspect powders, actual threats, and hoaxes. Beginning in October 2001, following the original "Amerithrax," or anthrax scares in the United States, Iowa experienced a large number of responses for suspicious powders. Following the development of a threat assessment/response protocol the number of responses was reduced.

The chemical terrorism history, fortunately, has been limited. There have been recent instances where public officials nationally have received suspicious letters, and this certainly can happen in Iowa. In 2005, a subject mailed rat poison to a number of state and local officials. There have been recent instances where public officials nationally have received suspicious letters, and this could happen in Iowa. One of the letters was torn open in a mail-sorting machine in Des Moines, which led to the closure of the city's main post office and the emergency room of Mercy Medical Center.

Incidents of agroterrorism have occurred in the state of Iowa. Over the past 10 years, Iowa has experienced incidents in which animal rights activists have vandalized or released animals in our agricultural facilities. Most prominently in 2004 animals were released from a University of Iowa lab. Recent clashes between activists and so-called factory farms have also been in the news recently. There has also been vandalism to agricultural facilities or incidents of disgruntled employees causing damage to animals and animal products. There are frequent cases of theft of agricultural machinery, products, and chemicals.

The Dakota Access Pipeline carries Bakken crude oil through Iowa and there have been issues that could be associated with terrorism. The pipeline was repeatedly damaged by two activists before it was put into operation. There were other peaceful protests as well.

There is no history of radiological terrorism in Iowa. Since there is almost no record of acts of nuclear terrorism, an approach other than the traditional approach to probability of occurrence is needed to estimate the probability of this type of occurrence. With no prior events by which to judge probability, it becomes necessary to consider the technical feasibility of radiological terrorism. Given that the radiation would kill anyone before they could amass enough material to produce a weapon, the threat is relatively low. Technical feasibility is important because whatever is feasible might also be realized and might happen. The threat is relatively low because it is not technically infeasible to construct such a weapon for terrorist uses.

There have been several issues within (and outside of) the state that could have ties to cyber terrorism and ability to connect to the Internet during the last few years. The incidences of these types of activities have increased and will likely continue to do so in future years.

Iowa HSEMD and the Iowa Department of Public Safety are partnering with the U.S. Department of Homeland Security to promote the "If You See Something, Say Something®," campaign, which was created to educate the public on the importance of reporting suspicious behavior that could indicate terrorism or terrorism-related crime. The private sector, through the Safeguard Iowa Partnership, and local law enforcement, through the Iowa State Sheriffs and Deputies Association and the Iowa Police Chiefs Association, are also partners in this effort.

With the recent school shootings throughout the United States, Iowa's governor has asked parents, students, school faculty and staff, and members of the community to be especially vigilant for signs of potential violence and to report it to school officials or law enforcement.

The "If You See Something, Say Something®," public awareness campaign includes the Say Something Iowa website and radio public service announcements. As part of this campaign, the Iowa Department of Education works with campaign partners to expand its efforts to spread the message on the importance of reporting suspicious activity. Past campaign efforts have included posters at the Iowa State Fair, statewide broadcast of radio public service announcements, billboards, bus signs, and community outreach through law enforcement.

3.4.7. Transportation Incidents

This hazard encompasses air transportation, highway transportation, railway transportation, and waterway incidents. A transportation incident is described as an accident involving any mode of transportation that directly threatens life, property damage, injury, or adversely impacts a community's capabilities to provide emergency services. Most transportation incidents are of short duration and limited impact.

A. Incidents - Air Transportation

An air transportation incident may involve a military, commercial, or private aircraft. Airplanes, helicopters, and other modes of air transportation are used to transport passengers for business and recreation, as well as thousands of tons of cargo. A variety of circumstances can result in an air transportation incident at or near an airport, including mechanical failure, pilot error, weather conditions, or an on-board fire. Air transportation incidents can occur in remote unpopulated areas, residential areas, downtown business districts, or at military, commercial, or private locations. An aircraft incident can also occur while the aircraft is on the ground.

As reported in Iowa's Report Card on Infrastructure, 2023, Iowa has a vast aviation inventory, totaling 114 public-use airports. Eight airports accommodate commercial air service. The remaining 106 are classified as general aviation airports, servicing a wide range of business, agricultural, and recreational craft. The overall condition of Iowa's aviation infrastructure is relatively stable. Iowa's airport network serves current passenger and freight demand with the FAA data indicating no delays due to traffic volume from 2013-2023. Pavement condition continues to deteriorate with age, dropping into the poor classification at some airports though most airports, 73%, remain in good or fair condition. While aviation funding has grown in recent years ($64.4 million annually between 2010 and 2019), work is still ongoing to replace or repair components in poor condition with an estimated annual need of $126.6 million.

From 1962 to 2010, there were approximately 2,035 (around 40 per year) air transportation incidents/accidents in Iowa according to the National Transportation Safety Board.

Between the first day of 2000 until the last day of 2017, there were 277 air transportation incidents (see https://www.ntsb.gov/_layouts/ntsb.aviation/index.aspx).

During the four-year period from 2018 through 2022, a search using the CAROL Query through the National Transportation Safety Board produced 51 incidents. Six incidents involved at least one fatality. Twelve involved a minor injury and six a serious injury. Twenty-six reported no injuries resulted from the incident and one incident had incomplete data.

Despite the increase in the number of people using air travel, incidents that require response personnel and involve casualties are not likely to increase due to advances in the quality of training, equipment, and safety. Proper land use near airports will also decrease the chance that people and property on the ground will suffer significant impacts in the event of an air transportation accident. Probably the most significant air transportation incident occurred in 1989 when 111 fatalities were recorded in the crash of United Flight 232 in Sioux City, Iowa.

B. Incidents - Highway Transportation

A highway transportation incident can involve a single vehicle or multiple vehicles, requiring responses exceeding normal day-to-day capabilities. An extensive surface transportation network exists in Iowa with local residents, travelers, and business and industry relying on this network on a daily basis. Hundreds of thousands of trips a day are made on the streets, roads, highways, and interstates in the state. When the designed capacity of the roadway is exceeded, the potential for a major highway incident increases. Weather conditions play a major factor in the ability of traffic to flow safely in and through the state as does the time of day and week. Incidents involving buses and other high-occupancy vehicles could trigger a response that exceeds the normal day-to-day capabilities of response agencies.

Numerous traffic accidents occur daily in Iowa and result in property damage and injury. Major accidents involving multiple vehicles and serious injury are not uncommon. As noted in the State Overview, Section 1.4 Highways and Roads:

> The primary road system (state highway network) which is managed by the Iowa Department of Transportation (DOT), represents 8.2 percent of the total road mileage in the state. However, in 2015 these roads carried 62.8 percent of all vehicular traffic. The weighted average daily count on Iowa's interstate highway system is 21,910 vehicles in rural areas and 42,689 in municipal areas.

The high volume of vehicular traffic and the concentration in urban areas is a documented trend identified by the DOT which is expected to continue. Specifically, "Iowa's population has become increasingly urbanized and population growth has primarily been concentrated around the state's nine metropolitan areas…more than half of the state's population has been located in…the ten largest counties."[135]

Despite the concentration of population and greater highway usage in the urban areas (ten of the ninety-nine Iowa counties), rural fatalities occur at more twice the rate of urban incidents resulting in fatalities.

2022 Iowa Traffic Fatality County for December 30, 2022. (Source: Iowa DOT)
https://iowadot.gov/mvd/stats/previous_daily.pdf

By Selected Crash Types (2017-2021 are end-of-year totals)

TYPE	2022	2021	2020	2019	2018	2017
Motorcycle	49	68	65	43	42	48
Bicycle	3	11	10	10	6	5
Pedestrian	17	32	30	22	22	24
ATV/UTV	11	4	9	7	5	6
Urban	103	113	101	98	55	73
Rural	235	243	242	239	264	258

Although traffic engineering, inspection of traffic facilities, land use management of adjacent areas to roads and highways, and the readiness of local response agencies have improved, highway incidents continue to occur. The combination of large numbers of people on the road, unpredictable weather conditions, potential mechanical problems, and human error create the potential for a transportation accident.

The Governor's Traffic Safety Bureau identifies traffic safety problems and implements programs to reduce death and serious injury. The Bureau's data collection and compilation reporting show high marks in seat belt usage at 95.2% and detail of relevant performance measures tied to other key indicators. Iowa Seat Belt Use Survey 2020 Data Collection Methodology Report (Source: Iowa DOT) https://iowadot.gov/mvd/stats/survey20.pdf

Iowa Motor Vehicle Crashes, 2020.

(Source: Iowa DOT) https://iowadot.gov/mvd/stats/crashhistory.pdf

Year	Fatal		Injury		Total Crashes	Licensed Drivers			Registered Motor Vehicles			Vehicle Miles Traveled[1]			Iowa Population	
	Fatalities	Fatal Crashes	Injuries	Injury Crashes		Licensed Drivers	Fatality Rate[3]	Total Crash Rate[3]	Registered Motor Vehicles	Fatality Rate[4]	Total Crash Rate[4]	Vehicle Miles Traveled	Fatality Rate[5]	Total Crash Rate[5]	Population	Fatality Rate[6]
2020	343	304	15,246	13,231	47,891	2,315,563	1.48	206.82	3,721,182	0.92	128.70	29,882	1.15	160.27	3,190,369	1.08
2019	336	313	18,612	15,476	58,554	2,307,392	1.46	253.77	3,715,039	0.90	157.61	33,779	0.99	173.34		1.10
2018	319	291	18,185	15,109	56,898	2,313,375	1.38	245.95	3,708,877	0.86	153.41	33,507	0.95	169.81		1.05
2017	331	302	19,087	15,796	56,000	2,284,337	1.45	245.15	3,665,098	0.90	152.79	33,751	0.98	165.92		1.09
2016	402	355	19,279	15,709	55,852	2,284,567	1.76	244.48	3,626,286	1.11	154.02	33,263	1.21	167.91		1.32
2015	321	283	19,110	15,291	54,847	2,249,188	1.43	243.85	3,576,933	0.90	153.34	33,109	0.97	165.66	3,046,355	1.05
2014	322	288	18,534	13,561	52,102	2,241,383	1.44	232.45	3,533,720	0.91	147.44	32,332	1.00	161.15		1.06
2013	317	290	17,694	13,091	50,009	2,187,268	1.45	228.64	3,501,115	0.91	142.84	31,542	1.01	158.55		1.04
2012	365	330	18,430	13,395	47,882	2,105,333	1.73	227.43	3,479,405	1.05	137.62	31,581	1.16	151.62		1.20
2011	360	329	28,396	13,479	48,793	2,038,806	1.77	239.32	3,465,040	1.04	140.82	31,411	1.15	155.34		1.18
2010	390	348	19,910	14,586	54,396	1,960,848	1.99	277.41	3,440,065	1.13	158.12	31,579	1.23	172.25		1.28

135 Iowa DOT State Transportation Plan, Iowa in Motion 2050, pg 15.

Iowa Highway Safety Plan, Revised, FFY 2023. Source: Iowa DPS.
https://dps.iowa.gov/sites/default/files/commissioners-office/governors-traffic-safety/Publications/FFY%202023%20HSP%20FINAL%20with%201st%20Quarter%20Amendments.pdf

Performance Report

Progress towards meeting state performance targets.

Performance Measure Name	Progress
C-1) Number of traffic fatalities (FARS)	A 2.08% increase in traffic fatalities was recorded between 2019 (336) and 2020 (343).
C-2) Number of serious injuries in traffic crashes (State crash data files)	A 4.22% decrease in serious injuries was recorded between 2019 (1,348) and 2020 (1,291).
C-3) Fatalities/100M VMT (FARS & FHWA)	Fatalities per 100M VMT was 1.148 in 2020. This was a 15.03% increase from 0.998 in 2019. (Preliminary State data).
C-4) Number of unrestrained passenger vehicle occupant fatalities, all seat positions (FARS)	Between 2019 and 2020, there was a 2.15% decrease in the number of unrestrained passenger vehicle occupant fatalities.
C-5) Number of fatalities in crashes involving a driver or motorcycle operator with a BAC of .08 or above (FARS)	Between 2019 and 2020, there was a 10.78% increase in the number of alcohol-impaired driving fatalities.
C-6) Number of speeding-related fatalities (FARS)	There was an 11.59% decrease in speeding-related fatalities between 2019 and 2020.
C-7) Number of motorcycle fatalities (FARS)	Between 2019 and 2020, there was a 45.45% increase in the number of motorcyclist fatalities.
C-8) Number of unhelmeted motorcyclist fatalities (FARS)	Between 2019 and 2020, there was a 22.86% increase in the number of unhelmeted motorcyclist fatalities.
C-9) Number of drivers age 20 or younger involved in fatal crashes (FARS)	After several consecutive years of a downward trend in the number of drivers age 20 or younger involved in fatal crashes, Iowa recorded a 51.52% increase between 2019 and 2020.
C-10) Number of pedestrian fatalities (FARS)	Between 2019 and 2020, there was a 28.57% increase in the number of pedestrian fatalities.
C-11) Number of bicyclist fatalities (FARS)	Iowa is seeing a fairly significant upward trend in the number of bicyclist fatalities. Bicyclist fatalities have increased 100% from 5 in 2017 to 10 in 2020.
Additional Performance Measure - #1: Rural Traffic Safety/Rural Traffic Fatalities	In spite of slight downward 5-year linear and moving averages trend lines, Iowa remains well above the national average for the percentage of rural fatalities. FFY 2023 will be the first year that Iowa has set a target for rural traffic fatalities.
Additional Performance Measure - #2: Distracted Driving	There were 7 more distracted driving fatalities in 2021 than there were in 2020. These were fatalities as a result of a distraction by use of cell phone of other device. FFY 2023 will be the first year that Iowa has set a target for distracted driving.
B-1) Observed seat belt use for passenger vehicles, front seat outboard occupant (Annual Survey)	The statewide safety belt usage rate decreased 2.67% between 2020 and 2021. The 2021 survey recorded a usage rate of 92.66%.

The objective of this analysis was to screen the Primary Highway System for the greatest potential for crash reduction (PCR) on highway segments. The analysis uses a safety performance function (SPF), which is an equation used to predict the average number of crashes per year at a location as a function of exposure and, in some cases, roadway characteristics. SPFs are regression equations that estimate crash frequency as a function of traffic volume and more realistically demonstrate the relationship between crashes and traffic volume.

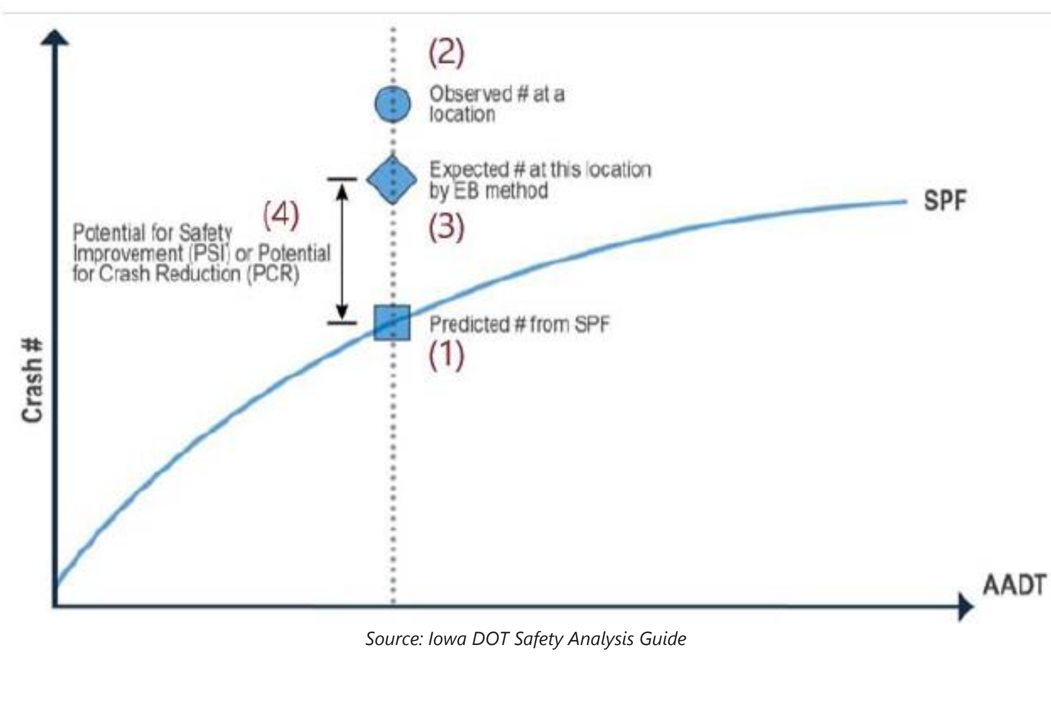
The figure below demonstrates how the PCR is calculated. The predicted number of crashes for a given traffic volume is found on the SPF curve (1). For any specific location, the observed number of crashes (2) is likely to be above or below the predicted number calculated by the SPF. The observed crash count is corrected using the Empirical Bayes (EB) method resulting in the expected number of crashes (3) at that location. The difference between the expected number and the predicted number is the PCR (4).

Highway segments were divided into eight classes of roadways for the analysis:

- Divided high speed
- Divided low speed
- Freeway high speed
- Freeway low speed
- Undivided high speed
- Undivided low speed
- Undivided multilane high speed
- Undivided multilane low speed

A model was developed for each class of roadway to develop individual SPFs in order to identify the PCR based on the roadway and traffic environment. A high PCR indicates a poorly performing roadway and more potential room for improvement. Segments can have negative PCRs, which suggests that they are performing better than predicted. For the purposes of the plan, positive PCR per mile was used to gauge risk, with higher values equating to higher risks and thus more potential for improvements that could help reduce future crashes.

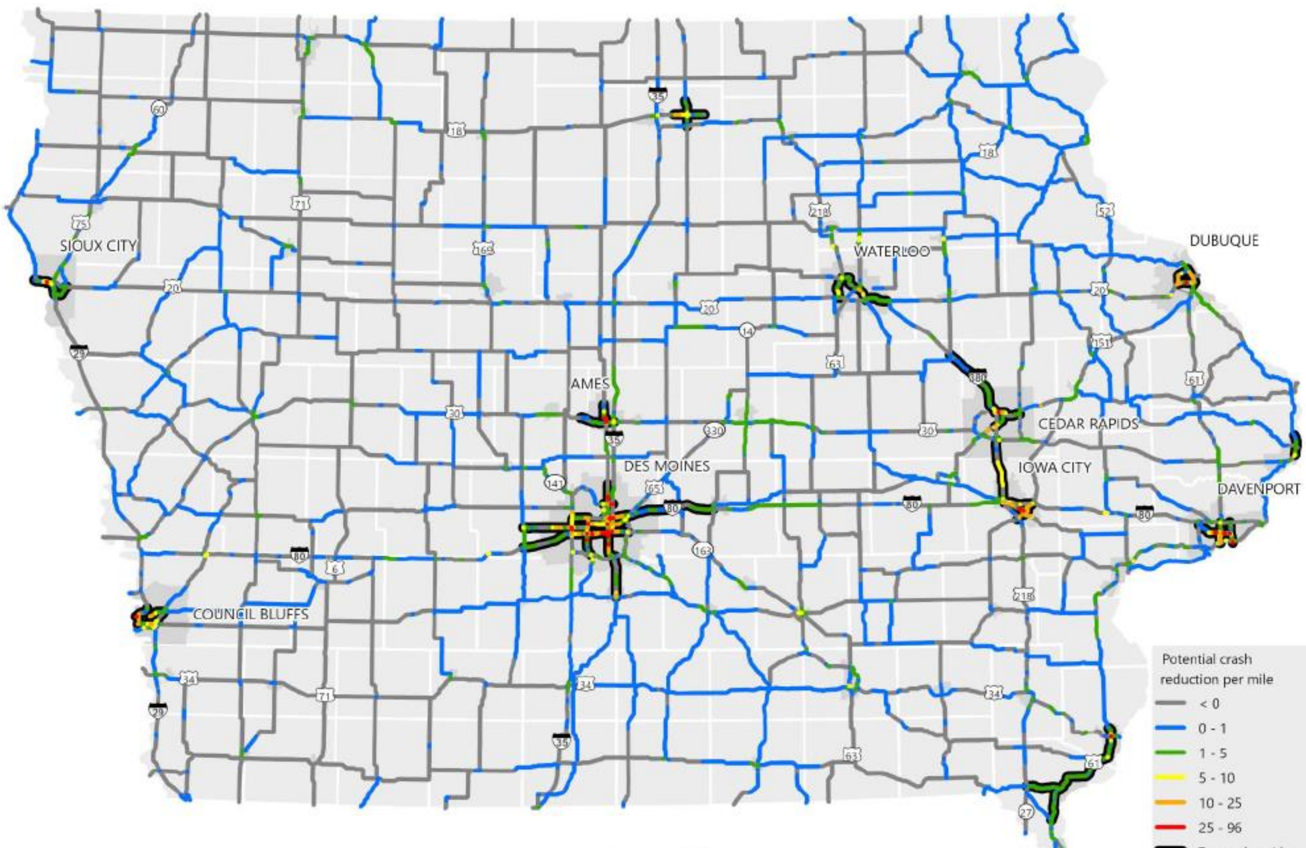
Potential for crash reduction (PCR) calculation



Source: Iowa DOT Safety Analysis Guide

The segment-level PCR output is shown on the figure above and below. The overall distribution of corridor-level positive PCR per mile ranged from 0.0 to 27.7, with a corridor-level average of 0.7. To identify corridors of most concern from a long-range planning standpoint, corridors that had 1.0 PCR per mile or more were identified, which would mean there is the potential to reduce crashes by at least one per mile throughout the corridor. There are 61 such corridors which are highlighted in Figure 5.20 (numbered from the *Iowa in Motion* Plan).

Figure 5.20: Potential for crash reduction per mile and corridors targeted for safety improvements – statewide view



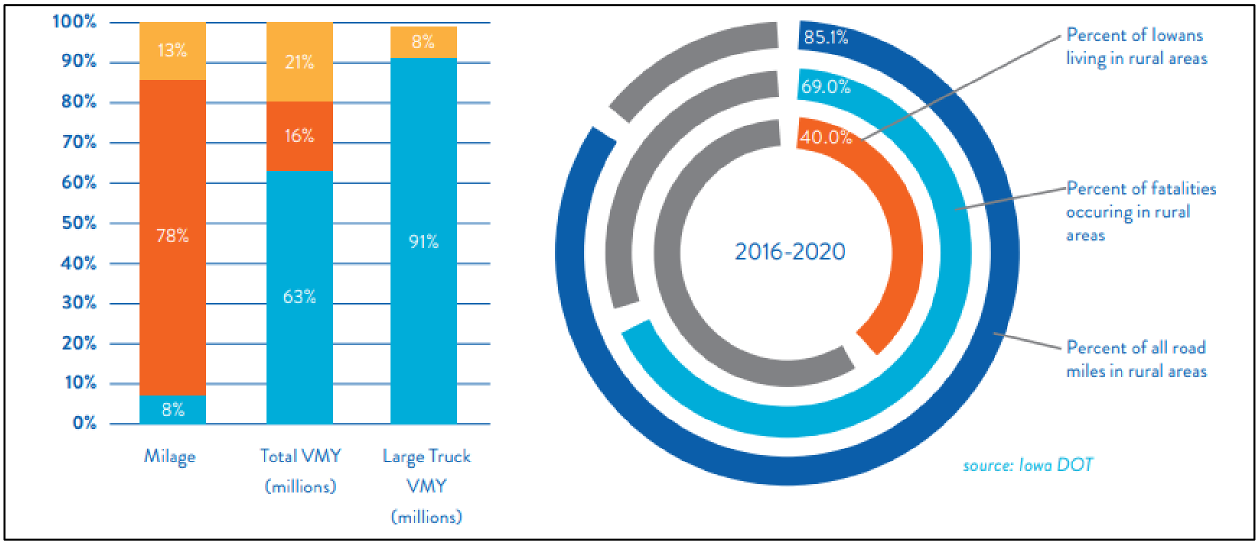
Source: Iowa DOT

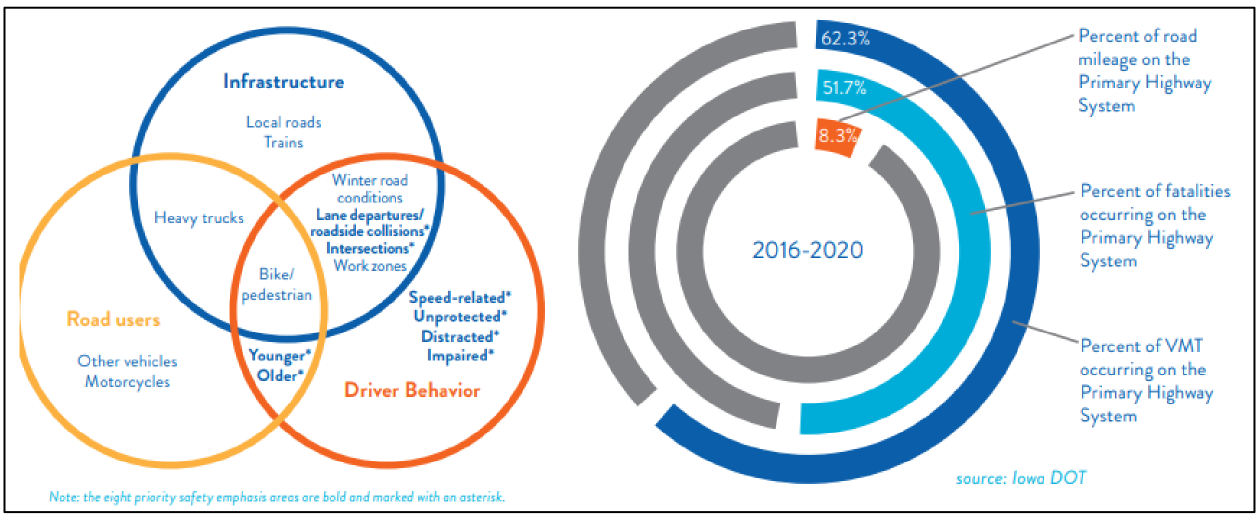
The State's Long-Range Transportation Plan (SLRTP) *Iowa in Motion 2050* contains goals and strategies to minimize incidents. Among them, two of the most relevant are strategies 27 and 28, below. With the identification of the strategies, policy, project assessment and funding can follow:

> **Strategy 27. Target investment to address locations with the most potential to improve safety through crash reduction.** Locations with the greatest potential for crash reduction (PCR) were identified based on a statewide analysis that calculated the PCR by examining the predicted numbers of crashes based on the roadway and traffic environment. For the purposes of the SLRTP, corridors that had an average of one or more PCR per mile were identified as the highest priority corridors from a safety perspective. These locations should be used to help focus consideration of safety improvements.
>
> **Strategy 28. Target investment to address corridors with higher risks from an operations perspective.** Target investment to address corridors with higher risks from an operations perspective. Corridors considered to be higher risk from an operations perspective were identified by using the Infrastructure Condition Evaluation for Operations (ICE-OPS) tool, which is a system screening tool that quantifies the relative risk to the safe and reliable

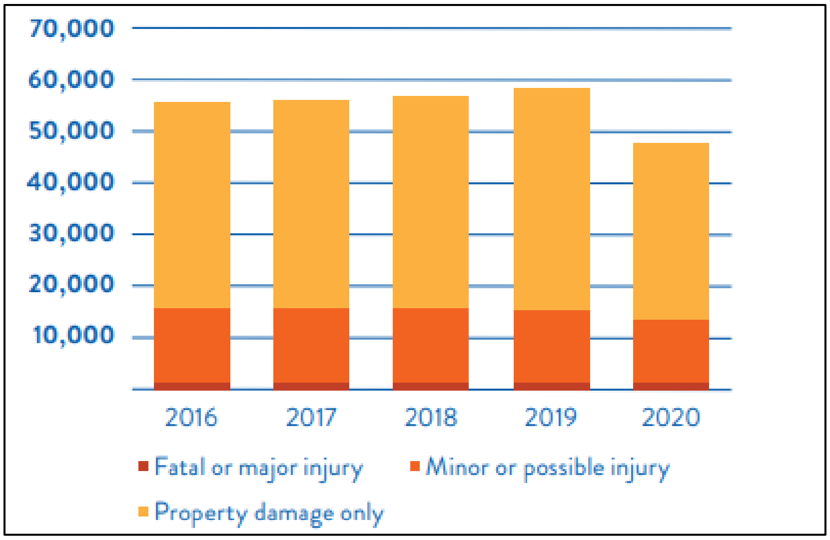
operation of the system. For the purposes of the SLRTP, corridors that were one or more standard deviation below the ICE-OPS statewide average composite score were identified as the highest priority corridors from an operations perspective. These locations should be used to help focus consideration of corridor operational improvements.

1. ***From 2023 Iowa Infrastructure Report Card*[136]**





136 See page 62. *Report Card* by Iowa Section, ASCE, American Society of Civil Engineers https://infrastructurereportcard.org/state-item/iowa/



C. Incidents - Railway Transportation

A railway transportation incident is a train accident that directly threatens life or property, or adversely impacts a community's capability to provide emergency services. Railway incidents may include derailments, collisions, and highway/rail crossing accidents. Train incidents can result from a variety of causes including human error, mechanical failure, faulty signals, or problems with the track. Results of an incident can range from minor track hops to catastrophic hazardous material incidents with human/animal casualties.

In Section 1 a map can be found that depicts the active rail lines to illustrate the areas in the state most at risk for rail accidents. Iowa has six passenger rail stations located in Creston, Osceola, Ottumwa, Mount Pleasant, Burlington, and Fort Madison. Iowa's transportation system includes approximately 4,470 public crossing and 3,400.private crossings. The table below shows the number of railway incidents that occurred at such highway-rail crossings. It also shows other train accidents that occurred from 2014 through 2022.

Each year brings a few train derailments of varying scope and impact. In September 2022, a Union Pacific train derailed impacting approximately 44 train cars and spilling asphalt into a creek. Earlier in the year in March, a 35-car train derailed carrying corn and grain. No injuries were reported from either incident. On the other end of the spectrum, in May 2021 after a weekend derailment of 47 cars, the nearby town of Sibley (pop. 3,000) was under an evacuation order. Several cars carried hazardous materials and the derailment caused a fire. The Iowa DNR leads the all cleanup efforts and enforcements actions in such incidents.

Federal Railroad Administration, Office of Safety Analysis

Category	2014	2015	2016	2017	2018	2019	2020	2021	2022
Number of railroads included	10	10	10	10	10	11	10	10	16
TOTAL ACCIDENTS/INCIDENTS 1/	20	14	16	19	15	14	9	20	13
--- Total fatalities	.	.	.	1	1	1	.	2	1
--- Total nonfatal conditions	13	11	9	17	8	7	7	10	7
TRAIN ACCIDENTS (Not at Grade-Crossings)	2	3	5	1	2	2	2	3	1
--- Train accident deaths	.	.	.	.	.	.	.	.	.
--- Train accident injuries	.	.	.	.	.	.	.	.	.
--- Derailments	2	1	4	1	2	1	1	2	1
--- HAZMAT RELEASES	.	.	.	.	.	.	1	.	.
HIGHWAY-RAIL INCIDENTS	6	2	3	6	6	4	1	7	6
--- Highway-rail incidents deaths	.	.	.	1	1	.	.	.	1
--- Highway-rail incidents injuries	1	.	1	5	.	.	.	1	1
OTHER ACCIDENTS/INCIDENTS 3/	12	9	8	12	7	8	6	10	6
--- Other incidents deaths	.	.	.	.	.	1	.	2	.
--- Other incidents injuries	12	11	8	12	8	7	7	9	6

1. *From 2023 Iowa Infrastructure Report Card*[137]

There have been 378 crashes between highway and railroad traffic and 331 train derailments in the past decade, with a relatively consistent number occurring each year. A total of 85 injuries and 98 fatalities resulted from those crashes and derailments. In spite of these incidents, Iowa continues a more than 30-year trend of decreasing crashes, with incidents leveling off in the previous decade. Iowa has 4,094 public and 2,441 private at-grade highway-rail grade crossings. Approximately 45% of the public crossings are actively protected, meaning they have flashing lights or have flashing lights with gates.

The Iowa Department of Transportation expects $25.7 million in federal funds for eliminating hazards at highway at-grade crossings. These funds matched, with local funds, provided $28.5 million to fund 107 projects from fiscal year 2019 to FY 2023. A study from Iowa DOT's Iowa Crash Analysis Tool identified driver behavior as the prominent challenge regarding railroad crossing safety. The typical one-mile grid pattern of Iowa roads in conjunction with increased train lengths has caused drivers to exhibit riskier

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[137] See page 54. *Report Card* by Iowa Section, ASCE, American Society of Civil Engineers https://infrastructurereportcard.org/state-item/iowa/

behavior in order to avoid multiple blocked crossings. These risky behaviors include motorists trying to beat a train by going around gates or taking other measures in an attempt to not be delayed.

In conjunction with infrastructure improvements, several education and awareness programs will continue to be implemented to decrease risky behavior and continue the trend of decreasing crashes. Bridges continue to be vulnerable, as most in operation were built over 100 years ago. On September 6, 2022, a Union Pacific train derailed near Hampton. The derailment included 44 cars and caused liquid asphalt to spill into Otter Creek. Fortunately, hazardous material crews were able to contain the asphalt and no crew members were hurt.

D. Incidents - Waterway Transportation

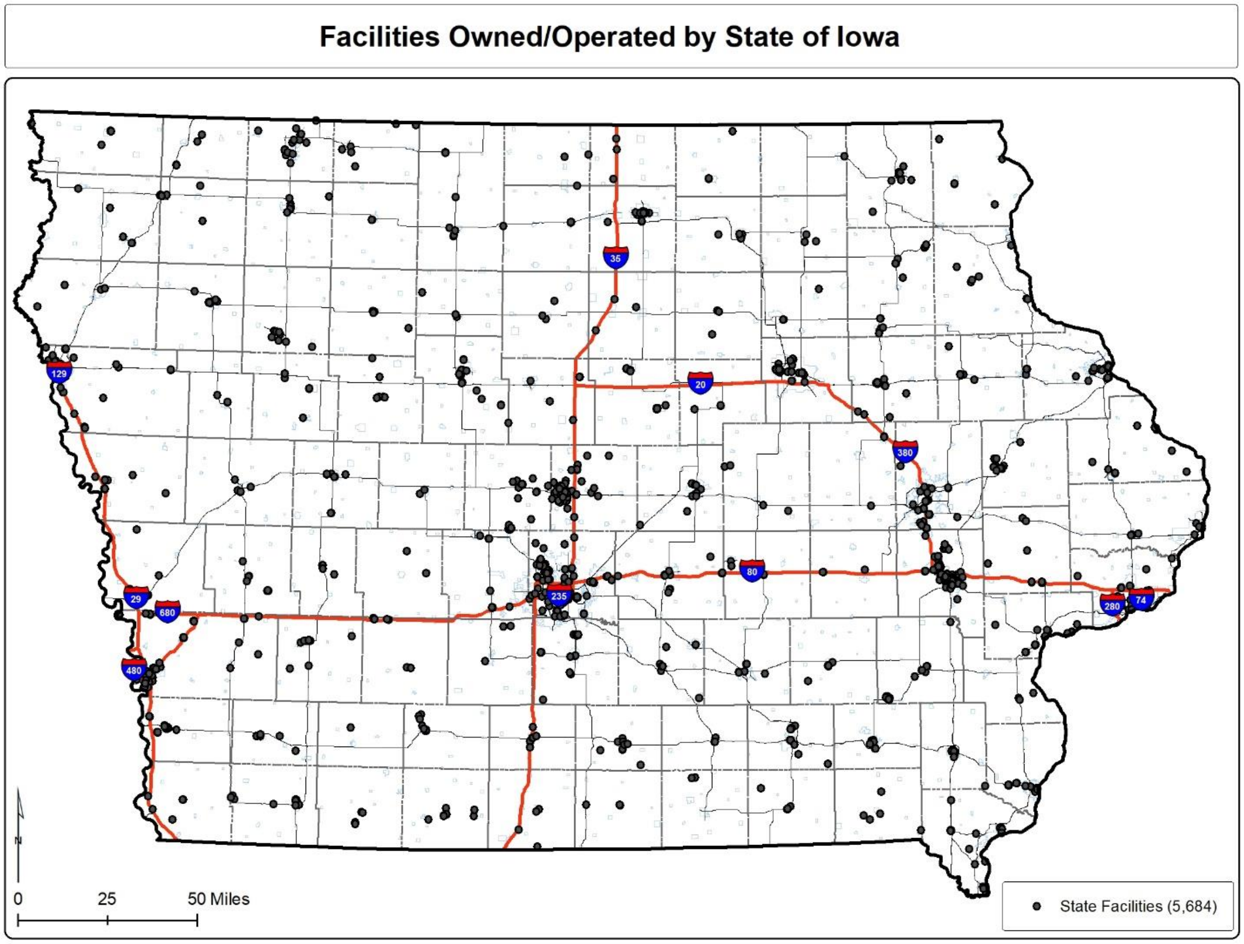
A waterway incident is an accident involving any water vessel that threatens life, property, or adversely affects a community's capability to provide emergency services. Waterway incidents primarily involve pleasure craft on rivers and lakes. In the event of an incident involving a water vessel, the greatest threat would be drowning, fuel spillage, and/or property damage. Water rescue events are largely handled by first-responding agencies. Waterway incidents may also include events in which a person, persons, or object falls through the ice on partially-frozen bodies of water.

There have been no large-scale disasters causing waterway incidents in Iowa. There have been numerous search and rescue events involving a single person or small boats with only a few people on board. Small-scale incidents on the state's lakes and rivers have resulted in the loss of life from pleasure craft collisions and/or falls from vessels. The only waterways navigable for commercial purposes in Iowa are the Mississippi and Missouri rivers. Each summer, thousands of Iowans and visitors take to pleasure crafts across the state. Thousands of visitors to the state's riverboat casinos board watercraft annually. The casinos make regular trips up and down the rivers during the summer months.

As reported in Iowa's Report Card for Infrastructure, 2023, Iowa has two inland waterways suitable for commercial use. "The Upper Mississippi River (UMR) and Missouri River provide an efficient and cost-effective transportation mode to export Iowa products. Waterways and ports contributed more than $18.7 billion in revenue to the state's economy and supported an estimated 101,000 jobs in 2018. However, revenue and security of jobs are threatened by aging navigation locks and dams. Their average age in Iowa is 85 years old, or 35 years past their intended design life. Unscheduled lock closures for maintenance cause delays and congestion, which can cost $739 per hour for an average tow. These costs are passed on to the consumer. Unexpected closures from 2010 to 2020 averaged 3,881 hours annually across Locks and Dam 9 through 18 in Iowa. Recent funding appropriated to the Navigation and Ecosystem Sustainability Program (NESP) will improve navigational capacity and provide ecosystem restoration."[138]

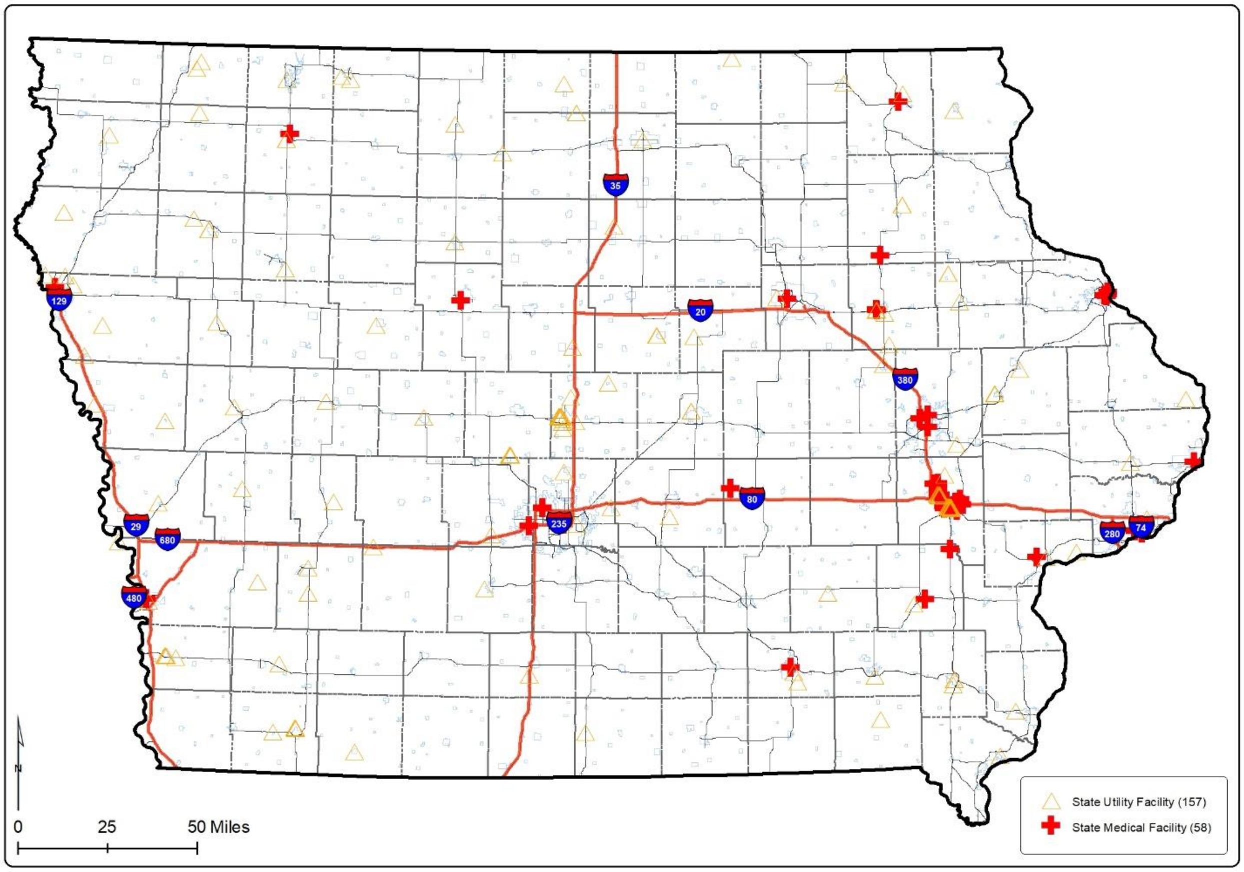
[138] https://infrastructurereportcard.org/state-item/iowa/

3.5. Vulnerability of State Facilities



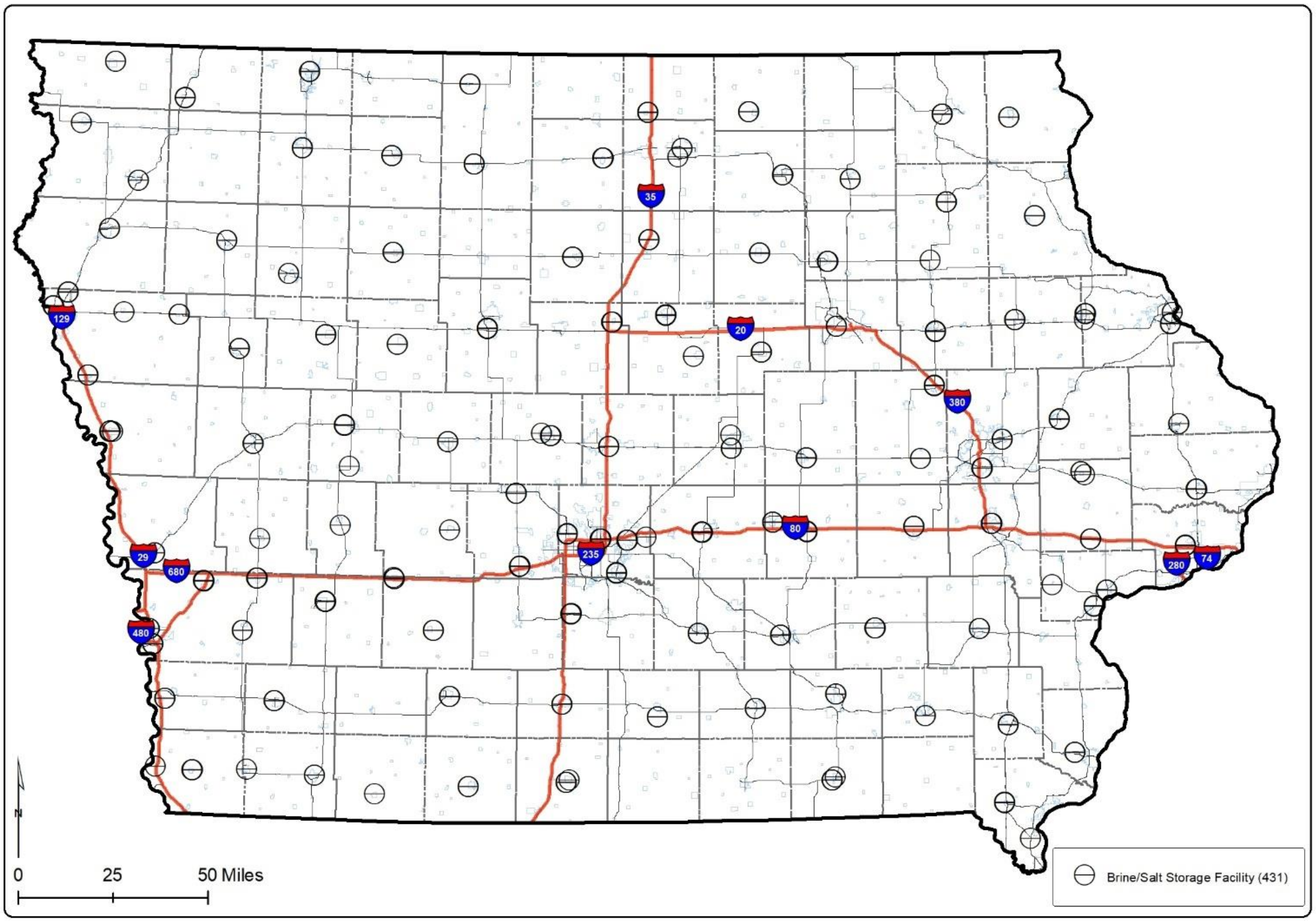
Section 3.3 of this chapter provided an overview and analysis of vulnerability to the natural hazards, and summarized vulnerability by showing the areas in the state that had the highest vulnerability for each hazard. This analysis of vulnerability looked at all the assets of the state, regardless of ownership. In this section, an examination will be made of just the facilities that are owned (or leased/operated) by the State of Iowa.

Utility and Medical Facilities Owned/Operated by State of Iowa



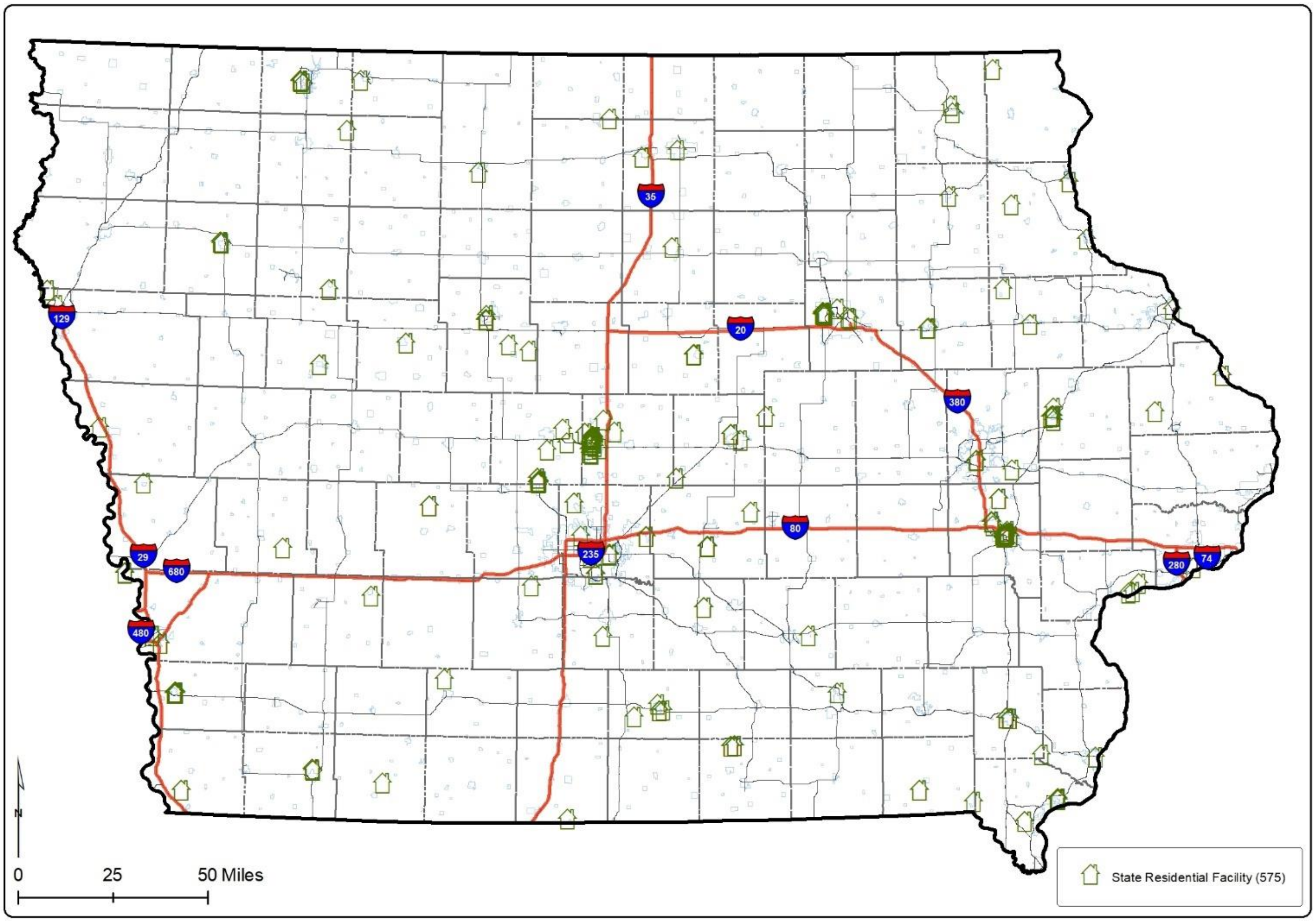
As presented in regards to several of the natural hazards examined in the different sub-sections of section 3.3, vulnerability is often discussed in terms of the dollar value of assets at risk. However, some facilities are critical or valuable in ways that cannot necessarily be expressed in dollars. Utilities and medical facilities are such facilities. State-owned utility and medical facilities have been identified in hazard areas of the state and will presented in this section. Determining what is "critical" or not is sometimes a matter of opinion. While utilities and medical facilities are generally agreed upon as critical, some other facilities are key to operations, necessary to maintaining emergency services, and essential for providing necessary basics. Facilities that help keep roads open and clear throughout the year, whether the sun is shining or blizzards abound, is an example of such a key facility. Though often overlooked, but certainly essential for keeping roads open, is the facility where salt or brine is stored so that it can be used to treat roads in severe winter weather and keep them open. The location of these will also be presented in this section. There are many such facilities, so if one is unavailable, the state has some resiliency, but it is good to identify which ones are at risk of which hazards.

Brine/Salt Storage Facilities Owned by State of Iowa



This section will also focus on one other type of state facility and identify where they are found in hazard areas. That type of facility is a residential facility. Unlike other state facilities, residential facilities are where people live, and if these facilities are severely impacted by hazards, the impact is not simply a matter of relocating operations – it means that someone could be injured, die, or at the very least be required to find another appropriate place to live. So, where state residential facilities are in hazard areas will also be presented in this section.

Residential Facilities Owned by State of Iowa



The upper limit, in terms of dollars, of the vulnerability of all state assets will be the total value of all state-owned or -operated facilities in Iowa. Through much research and analysis, valuations of nearly all state facilities were estimated. There were a few facilities for which valuations could not be determined, but values for 99% of the state's facilities were estimated. Estimates came from a variety of sources. A key resource was the 2022 Board of Regents 2022 Facilities Governance Report. That report provided per square foot values for many facility types, including academic classroom and offices, administrative offices, animal facility, athletics and recreation use, day care, hospital, laboratory, laboratory service, library, medical clinic, museum, parking garage, performing arts, residence or house, shop or storage, and student union. These values were multiplied by the square foot area of facilities as found in the state's facility inventory.

There were many facilities that did not fit nicely into the categories of the Facilities Governance Report. Value estimates for these came from a variety of sources. Facilities that are found in flood hazard areas were identified several years ago, and valuation methodologies from Hazus had previously been used to estimate the value of those facilities. These valuation estimates were updated to adjust for inflation. Other valuation estimates came from the recent costs of building new facilities, like rest areas, salt storage facilities, and even pedestrian bridges. For many facilities that the state leases, the valuation was estimated by multiplying the annual lease rate times a gross rate multiplier (GRM) of 8.3. Recent renovation costs were also used to provide estimated valuations. For example, a total value might be extrapolated from the per square foot cost for the renovation by applying it to the total square foot area of the entire facility. Specific industry trade journals provided other valuation estimates, especially for specialized facilities, like cell towers, radio equipment and data centers.

After much research and analysis, a total valuation of state buildings and similar facilities was estimated. The total estimate was $20.42 billion for 5,635 facilities (which is 99% of the 5,684 in the inventory). This represents an estimated total maximum exposure, or the upper limit of vulnerability, of state buildings/structures, no matter what the hazard.

Depending on the hazard, however, certain areas of the state have greater likelihood of impact. So, again depending on the hazard, state facilities in certain areas would have a greater likelihood of damage. Thus, the vulnerability of state facilities for a particular hazard will be less depending on what state facilities are in the hazard area. For each of the natural hazards to which Iowa is subject, vulnerability of state facilities in terms of dollars will be explained below, in separate sections for each natural hazard. Also, vulnerability of utility, medical, and residential facilities owned or operated by the state will be presented for those hazards that impact such facilities.

3.5.1. Levee and Dam Failure

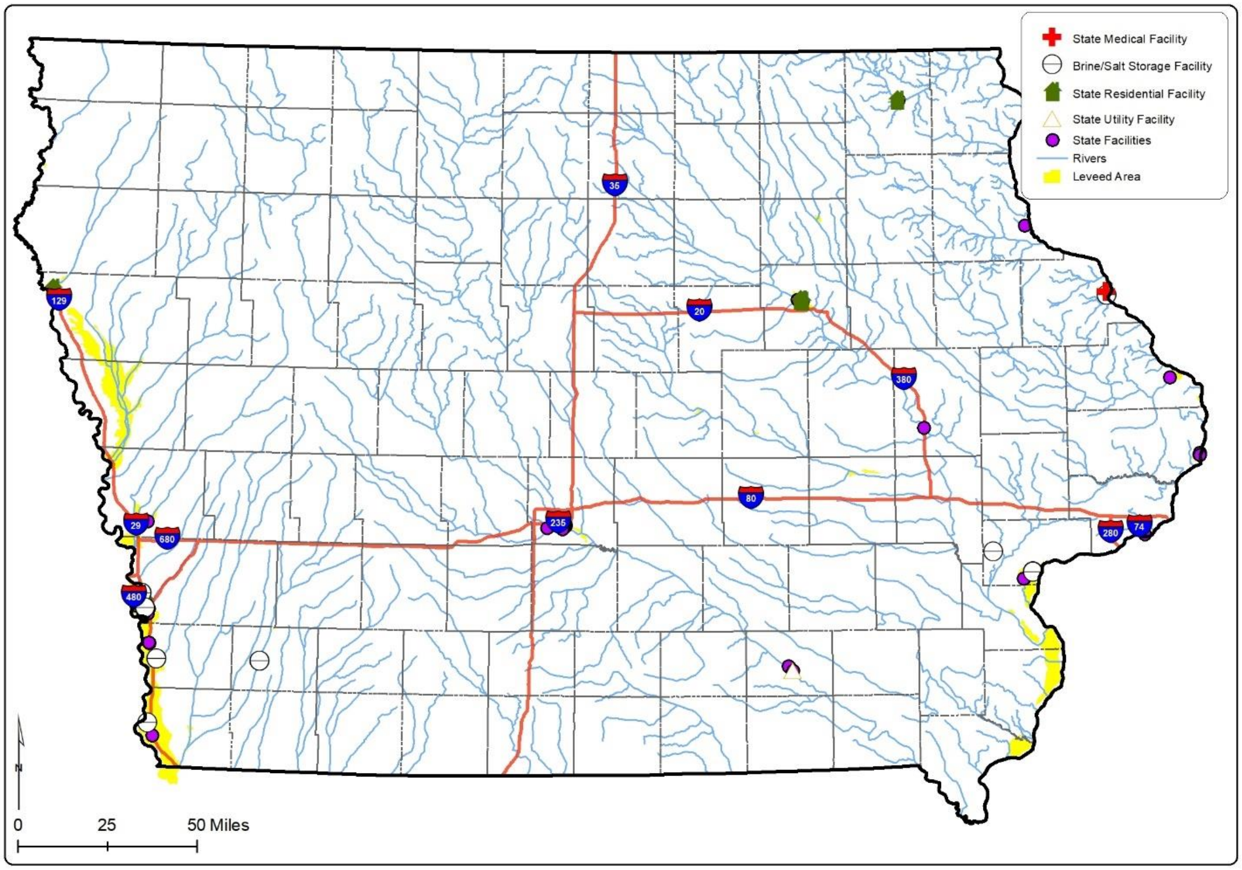
Vulnerability of State facilities to dam and levee failure cannot be completely determined because not all areas protected by dams and levees are known and mapped. The areas protected by levees found on the National Levee Database (NLD) are mapped, however, and HSEMD staff were able to identify 168 state facilities located in these areas. More than a third of the state facilities protected by NLD levees are in Pottawattamie County. Polk County has the second highest number, with over 20. The rest are in the following counties: Black Hawk, Clayton, Clinton, Dubuque, Fremont, Harrison, Jackson, Linn, Mills, Montgomery, Muscatine, Scott, Wapello, Winneshiek and Woodbury. The value of state facilities found in these levee-

County	Number of State Facilities Protected by NLD Levee	Sum of Estimated Values of Protected Facilities
BLACK HAWK	9	$26,211,295
CLAYTON	1	$165,733
CLINTON	3	$682,610
DUBUQUE	7	$27,045,807
FREMONT	3	$473,082
HARRISON	1	$158,763
JACKSON	2	$922,309
LINN	2	$2,955,751
MILLS	15	$15,904,814
MONTGOMERY	12	$4,051,067
MUSCATINE	7	$17,401,645
POLK	23	$105,661,236
POTTAWATTAMIE	64	$38,789,168
SCOTT	1	$131,657
WAPELLO	7	$2,338,364
WINNESHIEK	10	$3,214,680
WOODBURY	1	$12,181,755
Grand Total	**168**	**$258,289,736**

protected areas is estimated to be approximately $258.3 million[139]; the values of such facilities in each county are shown in the chart.

The map below shows the location of these state facilities in areas protected by NLD levees. Among those are 9 residential facilities (in Black Hawk, Dubuque, Pottawattamie, Winneshiek and Woodbury counties), one utility facility in Wapello County, one medical facility in Dubuque County, and 21 facilities that store road salt/brine (in Dubuque, Fremont, Mills, Montgomery, Muscatine and Pottawattamie counties). Most state facilities protected by NLD levees are either temporary use facilities at parks, or storage buildings.

State Facilities Behind Levees in National Levee Database (NLD)



To discover if any State facilities were in areas vulnerable to dam failures, geographic information systems (GIS) were used. GIS was used to create circles of one mile radius around high hazard dams and then the State facilities were plotted to see which state facilities fell inside those circles and thus in the vicinity of the dams. Several facilities did, but only a few were downstream of the dam; the rest were above the dam and therefore not vulnerable to dam failure. The only high hazard dams which were found to have State facilities below them were these USACE dams:

- Rathbun Dam
- Coralville Dam
- Saylorville Dam

[139] Estimates made by HSEMD in 2023.

- Red Rock Dam

The only State facilities vulnerable to a failure of the Rathbun Dam are at the Rathbun Fish Hatchery complex in Appanoose County. These facilities are at the foot of the dam and would most certainly be completely destroyed if the dam were to fail. These same facilities are also in the 500-year flood plain. The building cost for these facilities is estimated to be above $1.77 million.

While many State facilities are likely in the inundation pathway in the event of a Coralville Dam failure, they are not as easy to identify as those downstream from Rathbun. Failure of the Coralville Dam would impact an urban area and the impact to the state would be felt for over 100 miles along the Iowa and Mississippi Rivers, unlike the Chariton River which leaves the state less than 20 miles from the Rathbun Dam. From the data on State facilities found in the 500-year flood plain, it has been determined that all 22 such facilities in Johnson and Louisa counties would be inundated by a dam failure under the scenario in which Coralville is at the top of active storage pool[140] (TOS scenario). There are building and content cost estimates for all these facilities, which equate to about $426 million. However, several more State facilities, presently outside the 500-year flood plain, would also be inundated. At least three facilities considered critical are among those that would be impacted, including a power plant and two other utility structures.

The *Polk County Multi-jurisdictional Hazard Mitigation Plan* contains an analysis of the impact of the failure of the Saylorville dam based on inundation from a "Probable Maximum Flood-Failure" scenario[141]. The inundation area extends over a large portion of Des Moines. The analysis from Polk County's *Hazard Mitigation Plan* provides estimates of building values that are divided into several categories, one of which being "Government". The estimate of the values of government buildings (which includes both State of Iowa and other government) in the inundation path is $27,508,500[142]. Such State facilities include the Pappajohn Education Center, the Workforce Development Building on Des Moines Street, and the Oran Pape (Public Safety) Building.

Despite its large volume, it appears a failure of Red Rock Dam would impact relatively few State facilities, simply because there are few State facilities downstream of the dam along the Des Moines River. Several State facilities are located in Ottumwa, but only one would be inundated. It is a small structure with equipment for Iowa Public Television. Downriver near Farmington are some State Park facilities, but they appear to be located at an elevation high enough to avoid inundation. However, several State facilities in Lacey-Keosauqua State Park appear to be along the edge of the projected inundation area and may suffer some damage if the Red Rock Dam were to fail under a TOS scenario.[143] As these facilities are along the edge of the inundation zone, and they are relatively not of high value, it is estimated the dollar amount of damage to these facilities from a dam failure would be negligible.

3.5.2. Landslide

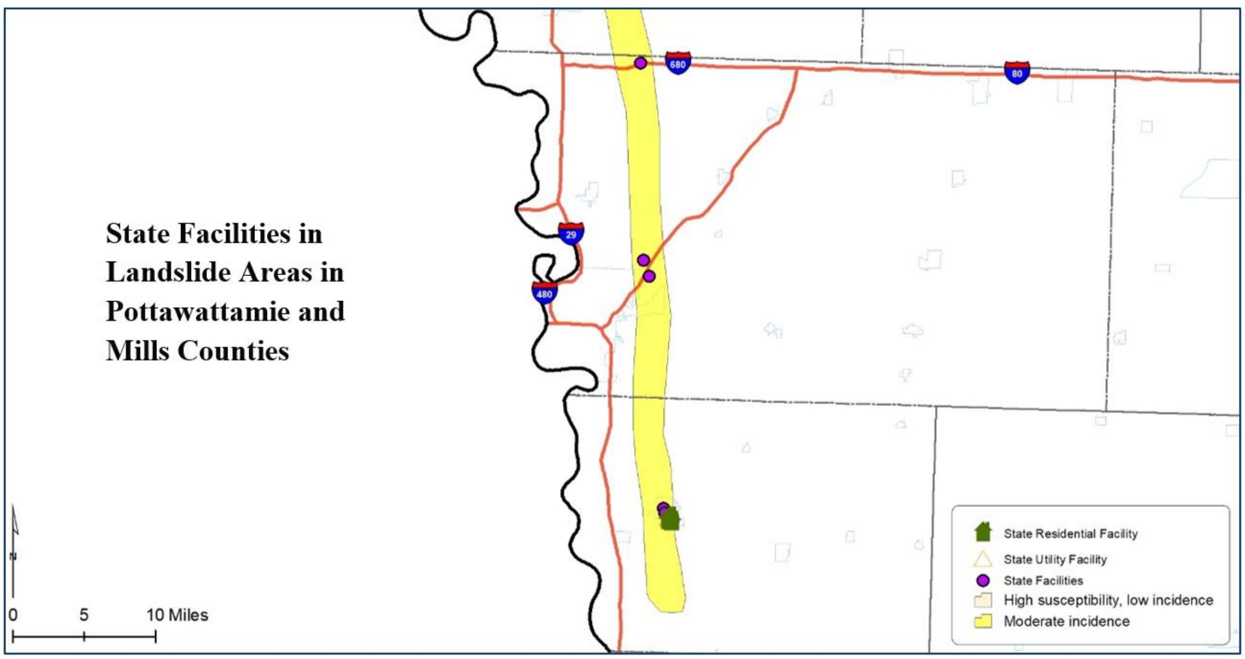
The areas susceptible to landslides, or with moderate incidence of landslides, are mapped and the map showing these areas statewide is found in section 3.3.8. GIS was used to find which state facilities were in

[140] The top of active storage (TAS) pool scenario corresponds to the highest elevation which can be obtained under normal regulated operating conditions for authorized purposes (i.e. without emergency spillway releases).
[141] Polk County, Iowa with AMEC Environment & Infrastructure, Inc. (2019). *Polk County, Iowa Multi-jurisdictional Hazard Mitigation Plan.* (Chapter 3)
[142] Ibid.
[143] USACE 2015. *Red Rock Dam Consequence Assessment Report.* (p. 13-14)

these areas of greater landslide threat. A total of 108 state facilities are located in these areas. The bulk of these are found in Mills County (45) and Jackson County (40). A considerable amount are also in Muscatine County (17). The other five are in Pottawattamie, Dubuque and Scott counties. The value of state facilities in these landslide-threatened areas is estimated to be approximately $224.1 million[144].

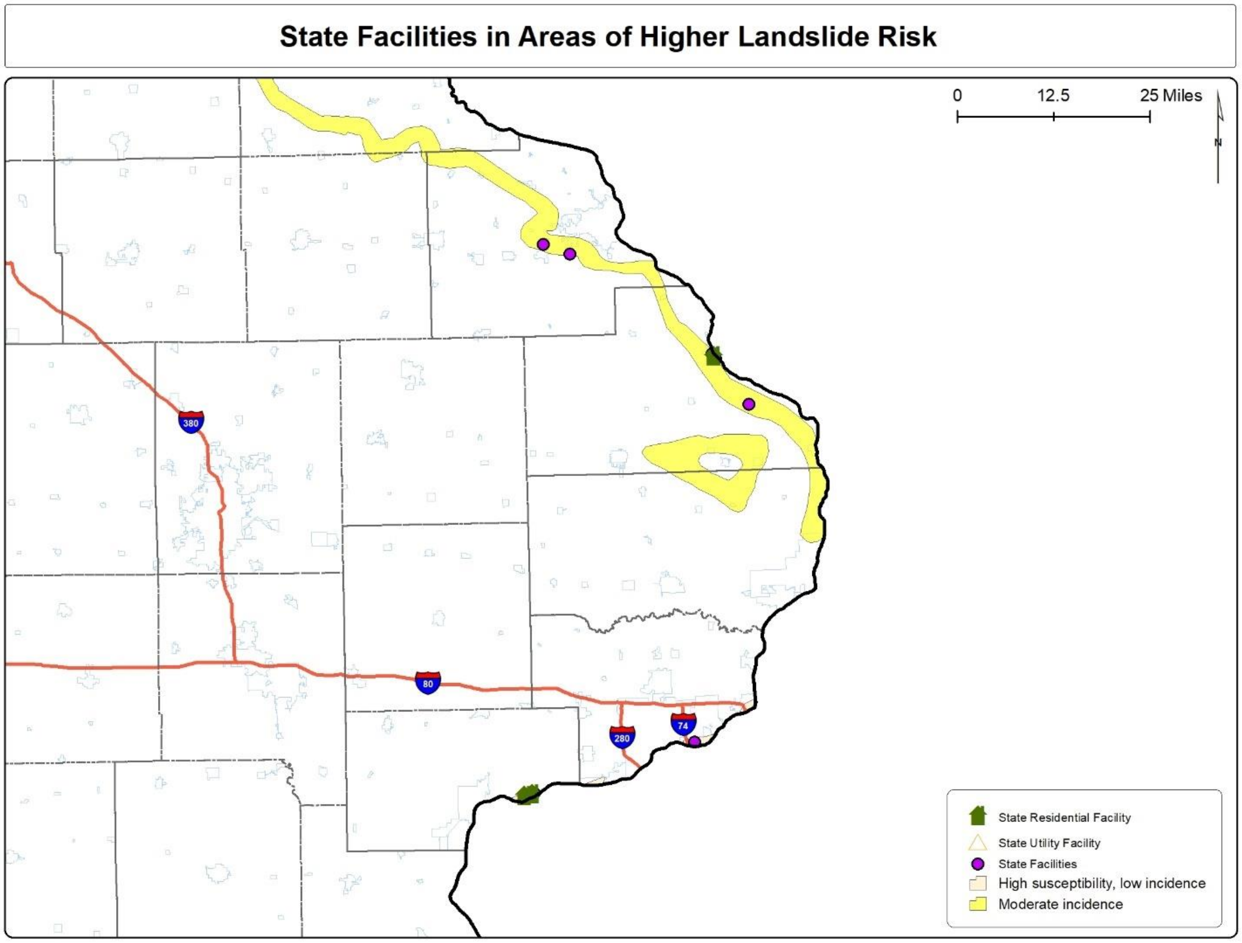
The chart shows the values of such facilities in each county.

County	Number of State Facilities in Areas with High Susceptibility or Moderate Incidence of Landslides	Sum of Estimated Values of Facilities
DUBUQUE	2	$35,481
JACKSON	40	$8,770,247
MILLS	45	$201,374,703
MUSCATINE	17	$8,252,083
POTTAWATTAMIE	3	$5,541,928
SCOTT	1	$131,657
Grand Total	**108**	**$224,106,099**



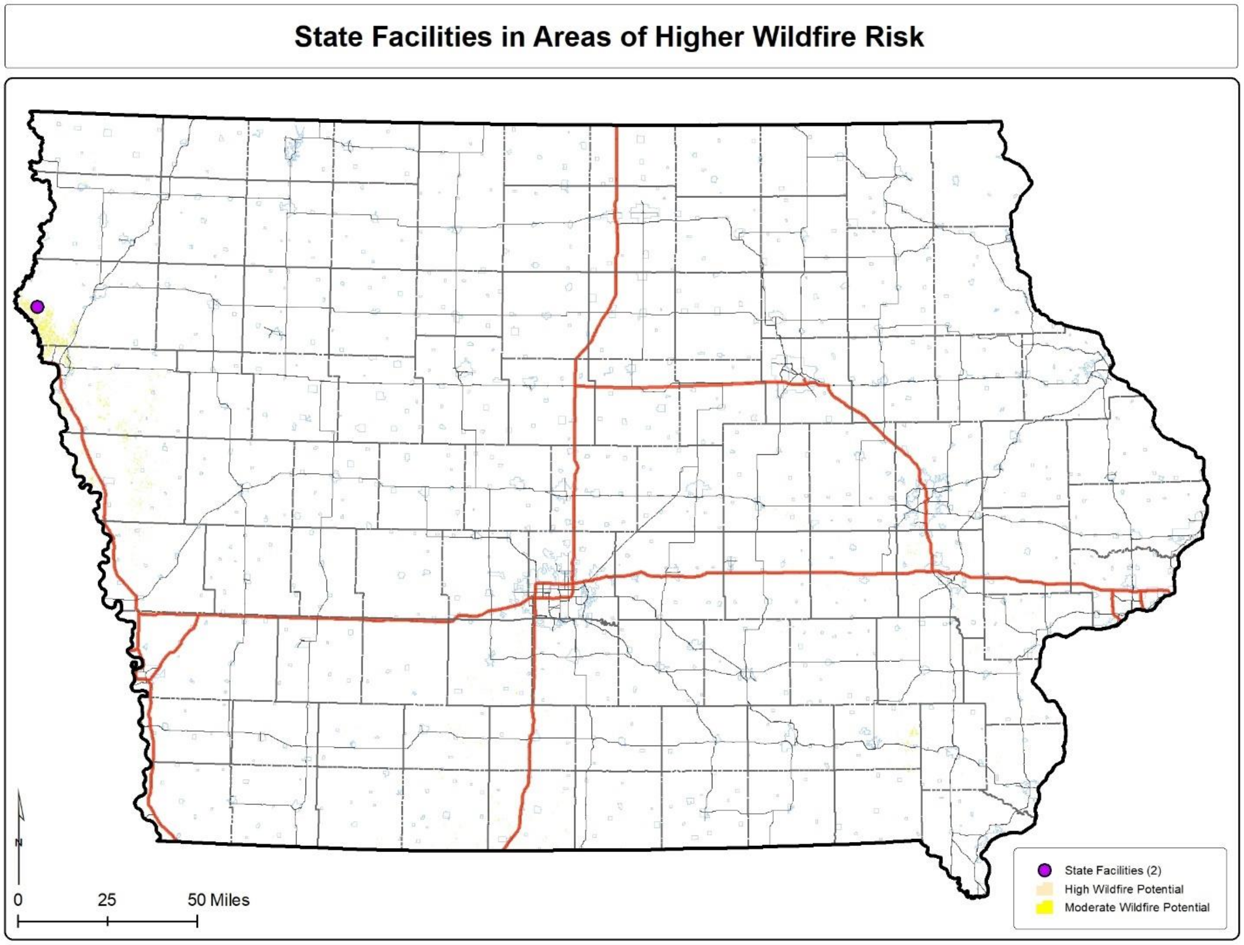
The map above (western Iowa) and the map below (eastern Iowa) show the location of these state facilities in the areas that have higher risk of landslides. Among those state facilities are four utility facilities in Mills County and 11 residential facilities in Jackson, Mills and Muscatine counties. (Neither medical facilities nor facilities that store road salt/brine are in landslide areas).

144 Estimates made by HSEMD in 2023.



3.5.3. Wildfire (and Grass Fire)

The areas in the state with higher Wildfire Hazard Potential (WHP) are shown in maps in section 3.3.10. A relatively small portion of the state has a wildfire hazard potential of moderate, high or very high. It should not be surprising, then, that only two state facilities are found in such areas. The two facilities are located in an area shown on the WHP map as having High wildfire potential. Both facilities are in Plymouth County. They are small buildings, having less than 250 square feet each, and their value, combined, is estimated to be between $50,000 and $60,000. They are not residential nor utility facilities, and are not considered critical. The map below shows their location.



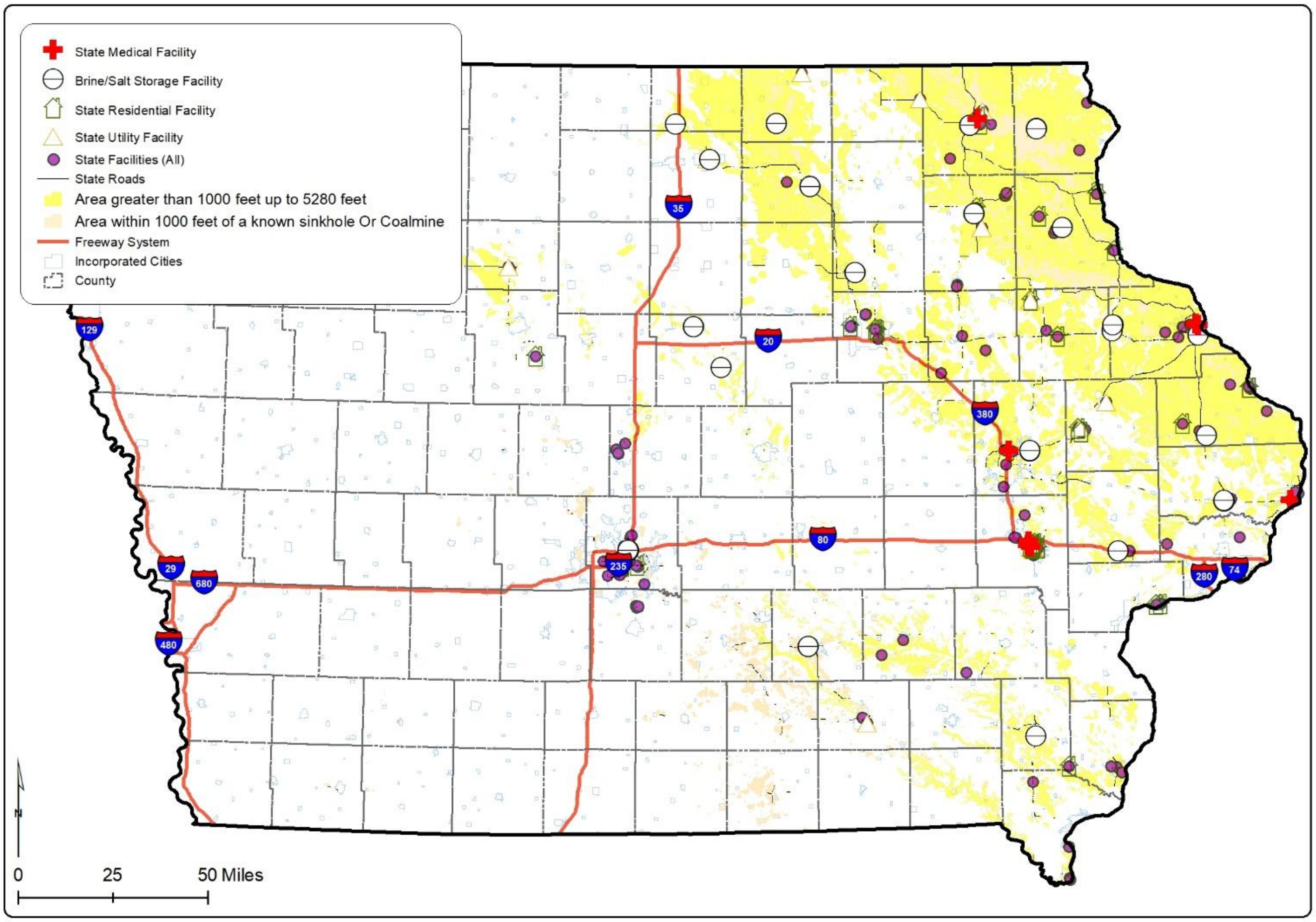
While GIS analysis shows only two state facilities in WHP areas designated moderate or greater in wildfire potential, that does not necessarily mean that state facilities are "out of the woods". Indeed, there are several DNR facilities in state parks that are literally in the woods. Most of these are restrooms, shower facilities, cabins, shelters, and other facilities associated with State parks. Because many of these facilities are in or near wooded areas, a great number of them may be considered more vulnerable to wildfire. However, besides the WHP map, there is not another data source to identify which or how many of these facilities are in areas of increased wildland fire potential.

3.5.4. Sinkholes

The areas close to existing sinkholes or old mines are discussed and mapped in section 3.3.11. These areas are considered more likely places for future sinkholes to form. Land in karst topography is also considered more likely for sinkhole formation. Such land, defined as having depth to carbonate bedrock of 50 feet or less, is also mapped and discussed in section 3.3.11. GIS was used to find which state facilities were in these areas of greater sinkhole threat, whether it be within 1000 feet of an existing sinkhole or mine, or between 1000 and 5280 feet (i.e. a mile) of a sinkhole or upon karst topography (depth to carbonate bedrock of 50 feet or less). The map below shows the locations of such state facilities.

A total of 869 state facilities are located in these areas. The value of state facilities in these areas is

State Facilities in Areas of Higher Risk of Sinkhole Formation



estimated to be approximately $3.24 billion[145]. The charts below contain information about the numbers of state facilities in such areas in each county, and the sum total of such facilities in each county. The first chart shows information about state facilities within 1000 feet of a known sinkhole or mine.

County	Number of State Facilities in Areas within 1000 feet of a Known Sinkhole or Mine		# Utility Facilities	# Medical Facilities	# Residential Facilities	# Brine/Salt Storage Facilities
Allamakee	8	$7,812,610	1			3
Clayton	3	$1,653,347			1	
Fayette	22	$1,580,993	3			
Floyd	5	$18,247,894				2
Jackson	32	$6,681,665			3	
Mahaska	9	$5,701,253				5
Polk	36	$117,815,429			1	7
Warren	13	$992,719				
Winneshiek	14	$8,143,170	1			6
Grand Total	**142**	**$168,629,080**	**5**	**0**	**5**	**23**

145 Estimates made by Iowa HSEMD in 2023.

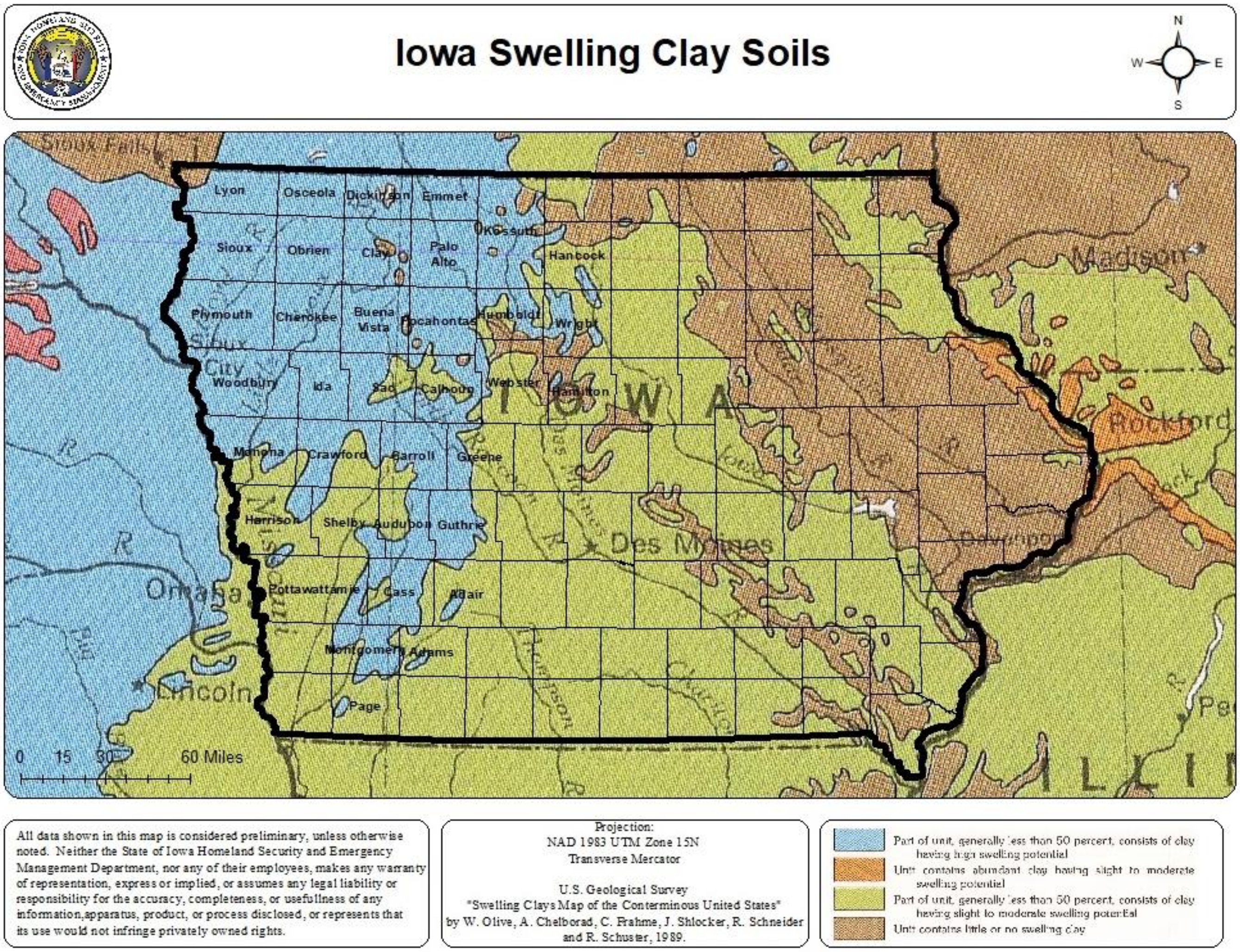
Among the more critical facilities above or close to abandoned mines are the Iowa State Patrol District 15 office and the 5th Judicial District Women's Center. As indicated in the chart, there are several other critical facilities either located near an abandoned mine or known sinkhole.

This next chart has information about the state facilities in areas that are between 1000 and 5280 feet of a sinkhole, or on land with depth to carbonate bedrock of 50 feet or less.

County	Number of State Facilities in Areas that are between 1000 and 5280 feet of a sinkhole, or on land with depth to carbonate bedrock of 50 feet or less		# Utility Facilities	# Medical Facilities	# Residential Facilities	# Brine/Salt Storage Facilities
Allamakee	56	$6,842,456				
Black Hawk	24	$218,324,040			4	
Bremer	9	$6,505,965				4
Buchanan	8	$1,788,220				
Cedar	15	$38,223,807				4
Cerro Gordo	10	$5,836,769	1			2
Clayton	41	$12,675,107		1	5	4
Clinton	17	$8,665,878		1		5
Delaware	75	$18,859,272	2		3	
Des Moines	3	$537,908				
Dubuque	51	$46,850,358		2		7
Fayette	33	$24,254,586			1	6
Floyd	5	$8,560,039				
Hardin	21	$18,602,086				9
Henry	24	$6,054,663			1	1
Howard	1	$512,569	1			
Humboldt	2	$532,561	1			
Jackson	38	$14,310,700			1	2
Johnson	115	$2,455,526,565	9	3	25	
Jones	26	$11,961,354	3		2	
Keokuk	2	$742,097				
Lee	5	$200,596				
Linn	22	$38,800,310		1		5
Mitchell	10	$8,181,954	1			4
Muscatine	17	$8,252,083			2	
Scott	9	$5,200,856				
Story	11	$87,549,356				
Wapello	7	$2,338,364	1			
Washington	1	$186,442				
Webster	26	$3,880,108			1	
Winneshiek	38	$11,138,286		1	2	
Worth	5	$324,504				1
Grand Total	**727**	**$3,072,219,859**	**19**	**9**	**47**	**54**

3.5.5. Expansive Soils

The areas in the state with soils that have more swelling potential are discussed and shown in section 3.3.12. The map of such areas is shown again for ease of reference.



The counties with a larger percentage of swelling soils are labeled on the above map. Approximately 743 state facilities are located in these counties in the area that have higher swelling potential. That number is approximate because the mapping is not very exact. The 743 total does not include state facilities that are in cities that appear not to be within the blue-colored area of the map (that is, the area where “Part of the unit, generally less than 50%, consists of clay having high swelling potential”). The value of state facilities in the blue areas is estimated to be approximately $614.2 million[146]. The chart below contains approximate amounts of the different types of state facilities in such areas in each county, and the sum total of the value of such facilities in each county.

[146] Estimates made by Iowa HSEMD in 2023.

County	Number of Estimates of State Facilities in Areas of Expansive Soils (where Part of the unit, generally less than 50%, consists of clay having high swelling potential)	Sum of Estimated Values of Facilities	# Utility Facilities	# Medical Facilities	# Residential Facilities	# Brine/Salt Storage Facilities
Audubon	5	$10,714,417	1	-	-	1
Buena Vista	41	$29,423,827	1	-	2	2
Calhoun	19	$65,328,605	1	-	2	2
Carroll	15	$14,388,655	1	-	-	4
Cass	45	$16,626,310	2	-	2	5
Cherokee	53	$135,314,325	4	-	7	3
Clay	29	$20,522,776	2	1	1	4
Dickinson	134	$60,013,504	1	-	22	4
Emmet	20	$17,767,508	2	-	1	-
Guthrie	45	$12,181,366	-	-	5	1
Ida	11	$4,043,294	1	-	-	4
Kossuth	24	$11,603,596	2	-	1	7
Lyon	8	$4,734,233	-	-	-	2
Monona	49	$35,386,613	2	-	1	5
Montgomery	37	$17,670,734	1	-	-	5
Obrien	4	$709,659	1	-	-	-
Osceola	9	$9,351,072	2	-	-	2
Palo Alto	10	$6,693,730	-	-	-	4
Plymouth	15	$14,035,463	1	-	-	3
Pocahontas	13	$6,116,882	-	-	-	4
Sac	46	$8,885,289	-	-	2	-
Sioux	15	$14,105,312	1	-	-	3
Woodbury	95	$98,570,857	5	1	3	19
Grand Total	**742**	**$614,188,027**	**31**	**2**	**48**	**84**

3.5.6. Flooding

The risk from riverine floods is the hazard for which there is the best data for analyzing and determining the vulnerability of State of Iowa facilities. As mentioned in the profile of the flood hazards, the Iowa DNR and Iowa Flood Center, with help from the U.S. Army Corps of Engineers and others, have been able to map the so-called 500 year flood plain, which is the area subject to a 0.2 percent chance of flooding each year. For all of these areas, depth grids were modeled by the IFC so the depth of flooding is estimated throughout the flood area for floods of several different frequencies (e.g. the 500-year flood, the 100-year, the 50-year, etc.). A list of State facilities was provided to HSEMD by Iowa’s Office of the Chief Information Officer (OCIO), the Department of Administrative Services and other State agencies. GIS was used to find which of these facilities fell inside the 500-year flood plain.

Hazus software was used to calculate the average annualized loss of the State facilities in the 500-year floodplain. This required several inputs first. Hazus can building replacement values given certain information about each facility. But, for this analysis, each agency that owned or utilized the facility simply provided a value or estimate. Likewise, the agencies provided content cost values.

The depth-damage curves and formulas included in the Hazus software were used to estimate percentage of damage (and thus dollar amounts of loss) due to flooding at the various flood frequencies (the depths of flooding at the various flood frequencies for each facility is from the depth grids mentioned above). To determine the dollar amount of damage at each depth, various factors are needed for the Hazus formula, such as occupancy type, building type, and foundation type. HSEMD staff were successful in discovering the actual occupancy, building, and foundation types for the Iowa Board of Regents (university) facilities, but for facilities of other State agencies assumptions were often made. For building types, all Department of Corrections facilities were assumed to be concrete, as were DNR restrooms and DOT rest areas. Remaining DOT facilities were assumed to have a steel building type. DNR shops (including concession stands) and storage buildings were also assumed to be steel. DNR shelters and lodging (including cabins and park ranger residences) were assumed to be a wood building type.

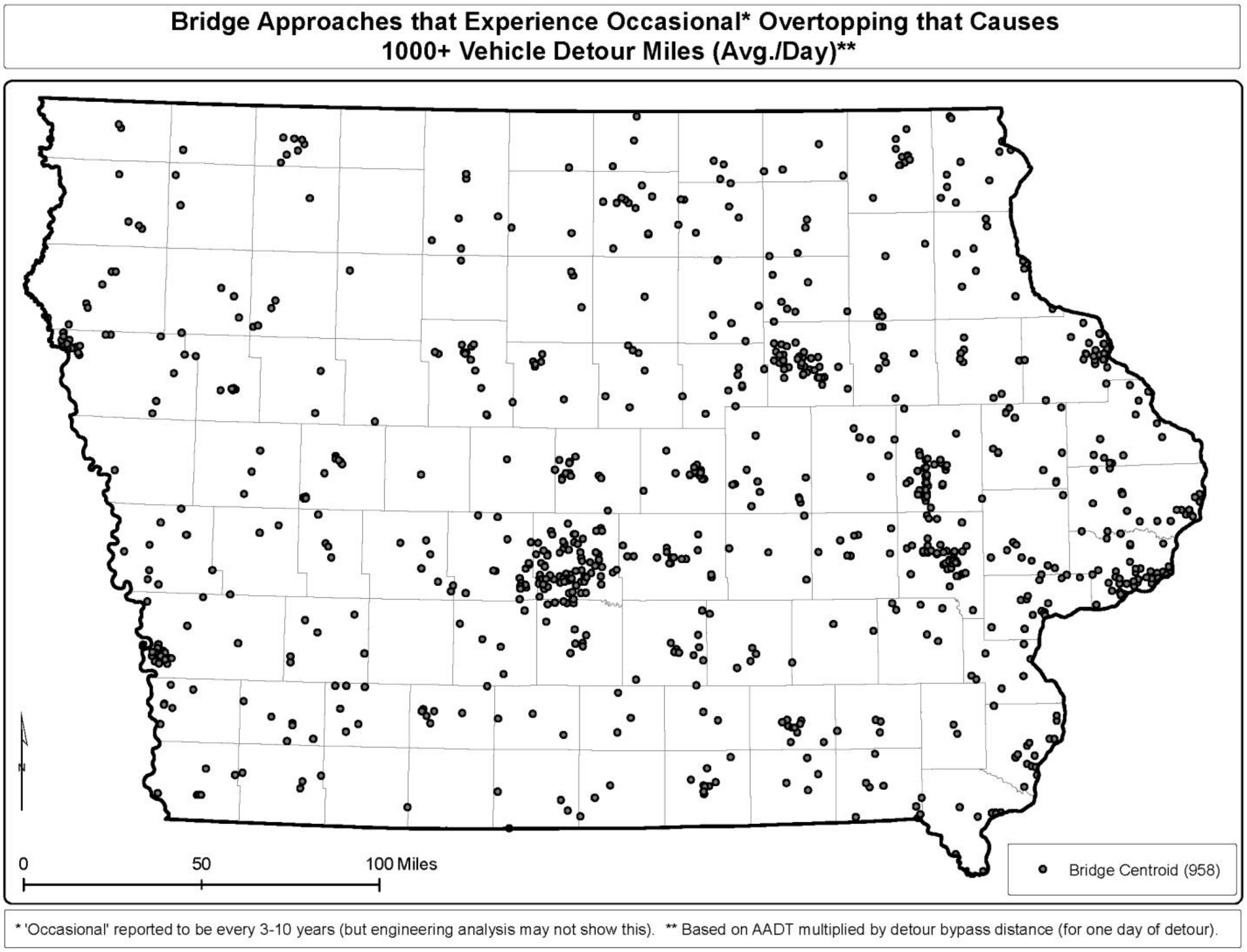
The following table summarizes the results of the analysis. (Values have been adjusted for inflation and updated as of June 2023).

Of the state facilities in the 500-year flood plain, the most critical include a radio transmitter building and power plant in Johnson County, Hilton Coliseum and an Iowa DOT facility with hazardous materials in Story County, and a water plant in Pottawattamie County. Also in Pottawattamie County are three salt/brine storage facilities and three residential facilities. Three other state-owned residential buildings are also located in Appanoose, Black Hawk and Hardin County (one in each county).

Annualized Average Loss of State Facilities, Due to Flooding, 2023. Source: Hazus analysis completed by HSEMD using flood data from Iowa DNR and Iowa Flood Center, and building data from State agencies (adjusted for inflation to year 2023)

		Estimated (2023)		Annualized Average Loss			
County	**# of Facilities**	**Building Cost**	**Content Cost**	Building Loss $	Content Loss $	Inventory Loss $	**TOTAL**
Allamakee	2	$87,447	$1,382	$538	$28	$1	**$89,396**
Appanoose	9	$1,790,406	$565	$515	$6	$6	**$1,791,498**
Black Hawk	11	$1,872,073	$43,374	$10,055	$1,192	$14,463	**$1,941,158**
Boone	3	$477,442	$754	$3,362	$19	$2	**$481,578**
Buchanan	1	$565,391	$63	$4,463	$3	$1	**$569,920**
Buena Vista	1	$628,213	$312,058	$10	$651	$1	**$940,932**
Cass	2	$100,514	$126	$139	$1	$1	**$100,782**
Clayton	4	$1,344,375	$251	$3,487	$4	$3	**$1,348,119**
Davis	3	$1,444,889	$1,382	$69	$3	$2	**$1,446,344**
Delaware	15	$4,648,773	$443,229	$13,963	$4,493	$9	**$5,110,467**
Emmet	1	$107,110	$251	$1	$1	$1	**$107,365**
Fayette	3	$131,925	$251	$16	$3	$2	**$132,197**
Fremont	4	$186,202	$45,420	$661	$640	$3	**$232,925**
Guthrie	1	$62,821	$63	$207	$1	$1	**$63,093**
Hardin	5	$257,643	$10,177	$1,109	$124	$3	**$269,057**
Harrison	3	$6,312,907	$653,341	$5,841	$2,917	$2	**$6,975,009**
Jasper	1	$94,232	$251	$264	$4	$1	**$94,751**
Johnson	21	$187,793,868	$241,484,803	$319,616	$630,967	$603,605	**$430,832,859**
Jones	7	$1,865,791	$32,219	$9,164	$739	$4	**$1,907,917**
Linn	2	$93,729	$503	$5	$1	$1	**$94,239**
Louisa	1	$241,234	$242,276	$69	$259	$1	**$483,839**
Lucas	2	$150,771	$28,596	$94	$398	$1	**$179,861**
Montgomery	4	$1,086,808	$108,756	$230	$5	$3	**$1,195,801**
Muscatine	7	$3,687,607	$283,449	$26,777	$2,344	$4	**$4,000,183**
Palo Alto	7	$5,521,360	$912,165	$692	$1,091	$4	**$6,435,311**
Polk	8	$2,427,225	$301,869	$6,478	$2,363	$8,986	**$2,746,921**
Pottawattamie	92	$27,693,190	$11,195,413	$35,907	$57,485	$58	**$38,982,053**
Shelby	2	$376,928	$126	$3,175	$4	$1	**$380,233**
Story	11	$216,261,216	$24,231,238	$219,059	$151,868	$85,411	**$240,948,791**
Tama	2	$188,464	$126	$3	$1	$1	**$188,594**
Warren	11	$1,299,420	$109,874	$5,018	$738	$7	**$1,415,057**
Winneshiek	7	$1,130,783	$503	$1,315	$6	$4	**$1,132,611**
State Totals	**253**	**$469,930,753**	**$280,444,854**	**$672,304**	**$858,358**	**$712,592**	**$752,618,862**

Flooding also impacts many state roads in Iowa, overtopping roads on occasion. Many of these events are short-term or happen infrequently and have little impact. But some roads are overtopped frequently and the detour is significant. The map below illustrates these locations where flooding impacts road travel in a significant way.

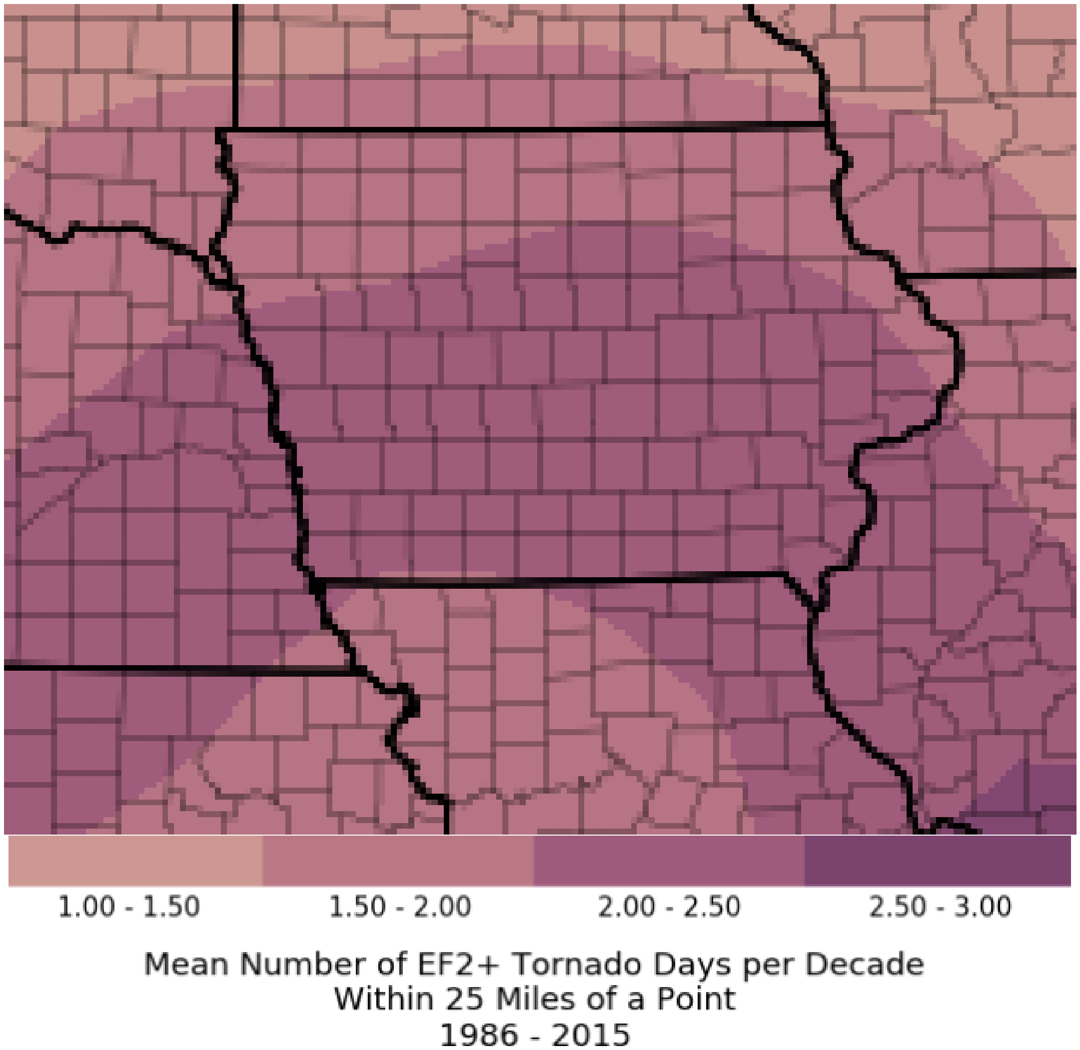


3.5.7. Tornado/Wind

From the map below, it would appear that state facilities in northern Iowa would have less vulnerability to tornadoes than those in southern Iowa. The map shows that, based on tornado occurrence between 1986 and 2015, northern Iowa has less likelihood of tornadoes than the rest of the state. But, vulnerability is not just the probability of occurrence. One way to measure vulnerability is by estimating expected annual losses (EAL). In the flooding section above, vulnerability to flooding was shown by estimating annual loss. The method used above was one used for flooding based on the probabilities of depths and damage functions that used the depth of flooding (in relation to a building) to estimate damage amounts. The damage estimates for the flood events of various recurrence intervals were then annualized to come up with a single annualized average. That method is quite good for flooding, where there is good modeling data.

Such data is not available for tornado and wind, but another method can be used to estimate expected annual losses.

Illustrating Probability of Significant Tornado Events. Source NWS Storm Prediction Center (https://www.spc.noaa.gov/wcm/climo/sigtorn.png)



FEMA's National Risk Index uses a particular method to estimate Expected Annual Loss (EAL). The NRI calculates EAL by multiplying exposure by annualized frequency and historic loss ratio (details about NRI's methodology may be found in *National Risk Index Technical Documentation, November 2021*[147]). Exposure is the value of the assets that could be impacted by a particular hazard. For the analysis shown in section 3.3.2, exposure is total value of all buildings as well as agriculture exposed to tornado and wind events. For our purposes, we need only be concerned with the exposure of state facilities to tornadoes and wind. In other words, we only need to use the value of state facilities for the *Exposure* component in the formula to calculate EAL. For the components of annualized frequency (*Freq*) and historic loss ratio (*HLR*), we can use the same figures that NRI used. These figures are calculated for each county. So, using the sum values of state facilities in each county (for *Exposure*), and the value of the product of *Freq X HLR* for each county, we can calculate EALs for vulnerability to tornadoes of state facilities in each county. The

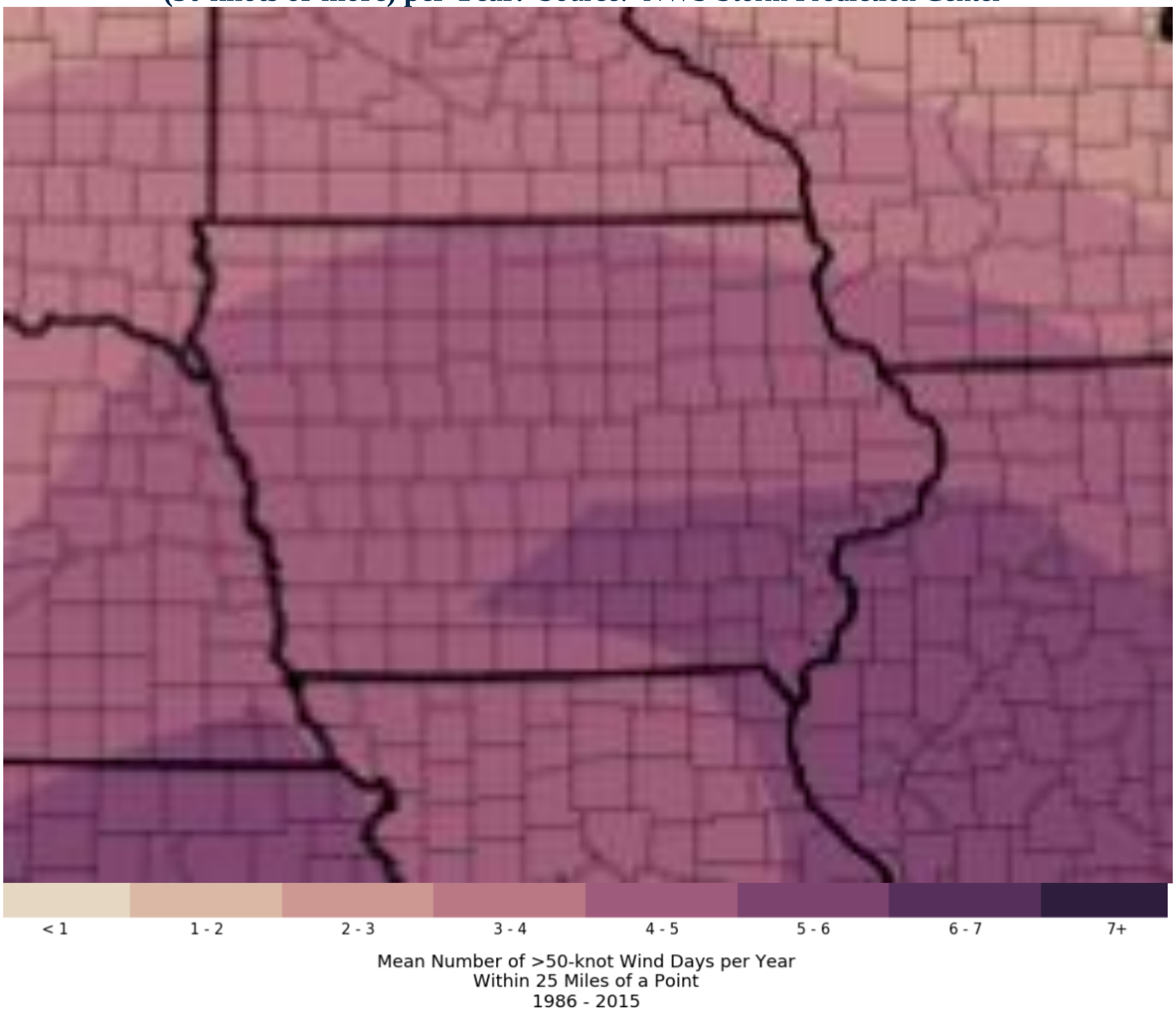
[147] http://www.fema.gov/sites/default/files/documents/fema_national-risk-index_technical-documentation.pdf

following chart illustrates these figures and calculations for the 20 counties with the highest resulting tornado EALs for state facilities in Iowa.

COUNTY	Value of State Facilities in County (Exposure)	X	Tornado Frequency (Freq)	X	Tornado HLR (buildings)	=	Tornado EAL (State Facilities)
Johnson	$7,507,480,321	X	57.57381%	X	0.10831%	=	$ 4,681,698
Story	$4,463,443,063	X	58.33977%	X	0.03926%	=	$ 1,022,233
Black Hawk	$1,922,472,605	X	52.96035%	X	0.03515%	=	$ 357,853
Polk	$1,903,705,687	X	57.16215%	X	0.02612%	=	$ 284,213
Mills	$281,399,500	X	36.76536%	X	0.07461%	=	$ 77,194
Boone	$337,582,685	X	57.71138%	X	0.03903%	=	$ 76,043
Lee	$376,742,504	X	37.03443%	X	0.04419%	=	$ 61,655
Pottawattamie	$198,902,571	X	78.98800%	X	0.03574%	=	$ 56,145
Marshall	$281,773,144	X	58.72213%	X	0.03362%	=	$ 55,627
Webster	$160,152,423	X	64.93523%	X	0.04407%	=	$ 45,832
Page	$191,041,938	X	41.70960%	X	0.04915%	=	$ 39,167
Cherokee	$135,314,325	X	49.38491%	X	0.05801%	=	$ 38,764
Jones	$197,339,179	X	52.03465%	X	0.03305%	=	$ 33,941
Henry	$214,282,446	X	34.62203%	X	0.04122%	=	$ 30,579
Buchanan	$220,398,229	X	48.47308%	X	0.02751%	=	$ 29,388
Linn	$121,004,328	X	66.70483%	X	0.03147%	=	$ 25,405
Woodbury	$98,570,857	X	69.33362%	X	0.03632%	=	$ 24,823
Jasper	$126,811,069	X	72.11039%	X	0.02456%	=	$ 22,455
Hardin	$82,417,827	X	56.17507%	X	0.03918%	=	$ 18,141
Calhoun	$65,328,605	X	49.54205%	X	0.05306%	=	$ 17,174

The map below illustrates the probability of wind in various parts of Iowa and the United States by showing the number of wind days per year averaged over the years 1986 to 2015. If the trends from 1986 to 2015 are any indication of future probability, then the map can be used to illustrate where high winds (over 50 knots) would be expected and how often: southeast Iowa would be expected to have more wind days per year (5-6) while northwest Iowa fewer (3-4 per year). But, that does not necessarily mean that vulnerability of state facilities to wind is greater in southeast Iowa compared to northwest. As explained above with tornadoes, vulnerability is not just the probability of occurrence.

Illustrating Probability of Wind, Reflected by Wind Days (50 knots or more) per Year. Source: NWS Storm Prediction Center[148]



To determine vulnerability of state facilities to wind, the same methodology will be used as with tornadoes above. So, using the sum values of state facilities in each county (for *Exposure)*, and NRI's values for Strong Wind Annual Frequency (*Freq)* and Strong Wind *HLR* for each county, Wind EALs for state facilities for each county are calculated. The following chart illustrates these figures and calculations for the 20 counties with the highest resulting wind EALs for state facilities in Iowa.

[148] https://www.spc.noaa.gov/wcm/climo/allwind.png

COUNTY	Value of State Facilities in County (Exposure)	X	Wind Annual Frequency (Freq)	X	Wind HLR (buildings)	=	Wind EAL (State Facilities)
Johnson	$7,507,480,321	X	633.172%	X	0.0046443%	=	$ 2,207,684
Polk	$1,903,705,687	X	652.212%	X	0.0018297%	=	$ 227,185
Story	$4,463,443,063	X	674.408%	X	0.0005736%	=	$ 172,655
Black Hawk	$1,922,472,605	X	611.603%	X	0.0006573%	=	$ 77,281
Jones	$197,339,179	X	645.972%	X	0.0049350%	=	$ 62,909
Buchanan	$220,398,229	X	590.997%	X	0.0036187%	=	$ 47,136
Henry	$214,282,446	X	556.672%	X	0.0038346%	=	$ 45,741
Lee	$376,742,504	X	464.592%	X	0.0019153%	=	$ 33,525
Boone	$337,582,685	X	637.889%	X	0.0014187%	=	$ 30,549
Marshall	$281,773,144	X	706.689%	X	0.0012686%	=	$ 25,262
Pottawattamie	$198,902,571	X	450.508%	X	0.0026312%	=	$ 23,577
Hardin	$82,417,827	X	687.065%	X	0.0031929%	=	$ 18,080
Jasper	$126,811,069	X	678.194%	X	0.0017386%	=	$ 14,952
Cedar	$44,416,862	X	645.277%	X	0.0047446%	=	$ 13,599
Cherokee	$135,314,325	X	443.800%	X	0.0021989%	=	$ 13,205
Page	$191,041,938	X	403.125%	X	0.0016630%	=	$ 12,807
Webster	$160,152,423	X	582.926%	X	0.0012980%	=	$ 12,118
Calhoun	$65,328,605	X	540.751%	X	0.0033986%	=	$ 12,006
Lucas	$51,610,093	X	552.570%	X	0.0039744%	=	$ 11,334
Woodbury	$98,570,857	X	406.621%	X	0.0023759%	=	$ 9,523

Note that the four counties that top either list above (Wind EALs or Tornado EALs) are the same counties. These counties are also the top four in terms of total exposure, i.e. total value of state-owned facilities in the county. Three of the four of these counties are locations of the three state public universities (University of Iowa in Johnson County, Iowa State University in Story County, and University of Northern Iowa in Black Hawk County). The other county in the top four is the location of the state capital (Polk County).

It is also interesting to note that in the lists above, each county's EAL for Tornado is higher than its EAL for Wind, with the exception of three counties; Jones, Buchanan, and Henry counties have a higher Wind EAL than Tornado EAL. These three counties are in the eastern side of the state. As it turns out, 30 of the 49 counties on the eastern half of the state have higher Wind EALs than Tornado EALs. But, only two of the 50 counties on the western half of the state have higher Wind EALs than Tornado EALs.

As for vulnerability of state-owned critical facilities, the threat of a tornado on the actual operation (regardless of dollar value of the facility itself) of such a facility is practically the same all across the state. As stated above in section 3.3.2:

> [N]o part of the state is significantly more susceptible to tornadoes than another part. Every part of the state needs to understand and prepare for the risk.

That is because the difference in frequency of a tornado occurrence one part of the state compared to another is really quite small (difference of just one tornado over 20 years). Therefore, the statewide maps of the various types of critical facilities found at the beginning of section 3.5 provide the best indication of locations of state-owned critical facilities that may suffer an impact to operations due to a tornado. As for which locations are more likely to experience wind events, and thus more vulnerable to disruptions in operations due to wind, the data from the NRI indicates that Tama, Poweshiek and Marshall Counties would be most likely to experience such disruption because they average the most strong wind events per year (between 7 and 8).

The NRI indicates that the following counties average 6 to 7 strong wind events each year (listed in order of greater average frequency): Hardin, Jasper, Story, Grundy, Polk, Jones, Cedar, Jackson, Boone, Linn, Hamilton, Johnson, Dallas, Benton, Muscatine, Clinton, Mahaska, Iowa, Black Hawk, Marion, Warren, Greene, Delaware, Dubuque, Scott, Guthrie, Louisa, and Madison. The critical facilities in these counties thus may be more vulnerable to disruptions due to wind than those found in the rest of the state except, as mentioned, those in Tama, Poweshiek and Marshall counties.

3.5.8. Severe Winter Storms

To determine the vulnerability of state-owned or -operated facilities to severe winter storms, an approach was used that is much like the one above for tornado/wind. This approach replicates the method used by FEMA's NRI to estimate Expected Annual Loss[149] (EAL) for each county in the state. The NRI calculates EAL by multiplying exposure by annualized frequency and historic loss ratio (HLR). For our purposes, we need only be concerned with the exposure of state facilities to winter storm events. In other words, we need to use the value of state facilities (and only state facilities) for the Exposure component in the formula to calculate EAL. For the components of annualized frequency (Freq) and historic loss ratio (HLR), we can use the same figures that NRI used for the various winter hazards found in the NRI. These figures are calculated for each county. So, using the sum values of state facilities in each county (for Exposure), and NRI's values for Cold Wave Annual Frequency (Freq) and Cold Wave HLR for each county, Cold Wave EALs for state facilities for each county are calculated. The following chart illustrates these figures and calculations for the 20 counties with the highest resulting Cold Wave EALs for state facilities for each county.

[149] NRI's methodology may be found in *National Risk Index Technical Documentation, November 2021*, or at http://www.fema.gov/sites/default/files/documents/fema_national-risk-index_technical-documentation.pdf

COUNTY	Value of State Facilities in County (Exposure)	X	Cold Wave Annual Frequency	X	Cold Wave HLR (buildings)	=	Cold Wave EAL (State Facilities)
Johnson	$7,507,480,321	X	0.988467874	X	0.0000000126	=	$ 93.51
Story	$4,463,443,063	X	1.235584843	X	0.0000000126	=	$ 69.49
Black Hawk	$1,922,472,605	X	1.72981878	X	0.0000000126	=	$ 41.90
Polk	$1,903,705,687	X	0.906095551	X	0.0000000126	=	$ 21.73
Boone	$337,582,685	X	1.317957166	X	0.0000000181	=	$ 8.05
Marshall	$281,773,144	X	1.15321252	X	0.0000000126	=	$ 4.09
Buchanan	$220,398,229	X	1.317957166	X	0.0000000126	=	$ 3.66
Jones	$197,339,179	X	1.15321252	X	0.0000000138	=	$ 3.14
Calhoun	$65,328,605	X	1.812191103	X	0.0000000181	=	$ 2.14
Linn	$121,004,328	X	1.317957166	X	0.0000000126	=	$ 2.01
Hardin	$82,417,827	X	1.72981878	X	0.0000000126	=	$ 1.79
Pottawattamie	$198,902,571	X	0.494233937	X	0.0000000181	=	$ 1.77
Scott	$127,333,001	X	0.988467874	X	0.0000000138	=	$ 1.73
Jasper	$126,811,069	X	1.070840197	X	0.0000000126	=	$ 1.71
Henry	$214,282,446	X	0.57660626	X	0.0000000138	=	$ 1.70
Lee	$376,742,504	X	0.329489291	X	0.0000000126	=	$ 1.56
Mills	$281,399,500	X	0.247116968	X	0.0000000216	=	$ 1.50
Woodbury	$98,570,857	X	0.741350906	X	0.0000000181	=	$ 1.32
Webster	$160,152,423	X	0.57660626	X	0.0000000126	=	$ 1.16
Cerro Gordo	$50,939,273	X	1.812191103	X	0.0000000126	=	$ 1.16

Besides Cold Wave, the NRI has two other types of winter hazards, Ice Storm and Winter Weather. EALs are calculated for those in a similar manner as for Cold Wave above. This next chart shows how the EALs for Ice Storm are derived for the 20 counties that ended up having the highest Ice Storm EALs for state facilities for each county.

COUNTY	Value of State Facilities in County (*Exposure)*	X	Ice Storm Annual Frequency	X	Ice Storm HLR (buildings)	=	Ice Storm EAL (State Facilities)
Johnson	$7,507,480,321	X	0.4000	X	0.00001275	=	$ 38,286.82
Story	$4,463,443,063	X	0.8361	X	0.00000214	=	$ 7,981.34
Mills	$281,399,500	X	0.9376	X	0.00002857	=	$ 7,537.28
Boone	$337,582,685	X	0.8285	X	0.00001915	=	$ 5,355.77
Pottawattamie	$198,902,571	X	0.9063	X	0.00002857	=	$ 5,149.43
Calhoun	$65,328,605	X	0.7595	X	0.00006873	=	$ 3,410.35
Lee	$376,742,504	X	0.3524	X	0.00002528	=	$ 3,355.62
Page	$191,041,938	X	0.5807	X	0.00002857	=	$ 3,169.12
Monona	$35,386,613	X	0.7289	X	0.00005564	=	$ 1,435.16
Black Hawk	$1,922,472,605	X	0.4206	X	0.00000177	=	$ 1,427.64
Dubuque	$78,482,456	X	0.4612	X	0.00003888	=	$ 1,407.27

COUNTY	Value of State Facilities in County (*Exposure)*	X	Ice Storm Annual Frequency	X	Ice Storm HLR (buildings)	=	Ice Storm EAL (State Facilities)
Marshall	$281,773,144	X	0.7530	X	0.00000623	=	$ 1,322.25
Webster	$160,152,423	X	0.4413	X	0.00001766	=	$ 1,248.16
Buchanan	$220,398,229	X	0.2833	X	0.00001884	=	$ 1,176.49
Harrison	$21,700,020	X	0.8927	X	0.00005564	=	$ 1,077.77
Jones	$197,339,179	X	0.3507	X	0.00001502	=	$ 1,039.30
Henry	$214,282,446	X	0.4110	X	0.00001156	=	$ 1,018.26
Polk	$1,903,705,687	X	0.8873	X	0.00000059	=	$ 1,004.08
Crawford	$17,185,886	X	0.6957	X	0.00008072	=	$ 965.12
Carroll	$14,940,250	X	0.6239	X	0.00007786	=	$ 725.77

This next chart shows how the EALs for Winter Weather are derived for the 20 counties that ended up having the highest Winter Weather EALs for state facilities for each county.

COUNTY	Value of State Facilities in County (Exposure)	X	Winter Weather Annual Frequency	X	Winter Weather HLR (buildings)	=	Winter Weather EAL (State Facilities)
Story	$4,463,443,063	X	4.942	X	0.000001308	=	$ 28,858
Black Hawk	$1,922,472,605	X	5.601	X	0.000002389	=	$ 25,728
Dickinson	$60,013,504	X	5.107	X	0.000025921	=	$ 7,945
Mills	$281,399,500	X	2.965	X	0.000008915	=	$ 7,440
Boone	$337,582,685	X	4.283	X	0.000004075	=	$ 5,892
Polk	$1,903,705,687	X	4.448	X	0.000000657	=	$ 5,560
Page	$191,041,938	X	2.883	X	0.000008915	=	$ 4,910
Marshall	$281,773,144	X	4.942	X	0.000003324	=	$ 4,629
Pottawattamie	$198,902,571	X	3.130	X	0.000005107	=	$ 3,180
Buchanan	$220,398,229	X	4.366	X	0.000003107	=	$ 2,990
Clay	$20,522,776	X	4.778	X	0.000027005	=	$ 2,648
Calhoun	$65,328,605	X	4.448	X	0.000006672	=	$ 1,939
Jasper	$126,811,069	X	4.119	X	0.000003423	=	$ 1,788
Hardin	$82,417,827	X	5.437	X	0.000003804	=	$ 1,704
Sioux	$14,105,312	X	4.201	X	0.000024450	=	$ 1,449
Osceola	$9,351,072	X	4.695	X	0.000027930	=	$ 1,226
Lucas	$51,610,093	X	2.801	X	0.000005616	=	$ 812
Emmet	$17,767,508	X	5.848	X	0.000007180	=	$ 746
Appanoose	$44,024,398	X	3.130	X	0.000004756	=	$ 655
Johnson	$7,507,480,321	X	3.707	X	0.000000023	=	$ 638

Comparing the EALs of the three different winter hazards, it is apparent the Expected Annual Losses from a Cold Wave are relatively small. Comparing the county EALs for the other two winter hazards, one notices that the three counties with the highest exposure are first or second in at least one of the lists. Story County is in the top two counties in both lists. These are the three counties where the state's public universities are located.

3.5.9. Hail and Lightning from Thunderstorms

To determine the vulnerability of state-owned or -operated facilities to hail and lightning, the same approach is used as used above for winter storms and tornado/wind. Again, this is the same approach as used by FEMA's NRI to estimate Expected Annual Loss[150] (EAL) for each county. The NRI calculates EAL by multiplying exposure by annualized frequency and historic loss ratio (HLR). For our purposes, we are only concerned with the exposure of state facilities to hail and lightning. So, we just need to use the value of state facilities (and only state facilities) for the Exposure component in the formula to calculate EAL. For the components of annualized frequency (Freq) and historic loss ratio (HLR), we can use the same figures that NRI used for the Hail and Lightning hazards in the NRI. These figures are determined for each county. So, using the sum values of state facilities in each county (for Exposure), and NRI's values for Hail Annual Frequency (Freq) and Hail HLR for each county, Hail EALs for state facilities for each county are calculated. The following chart illustrates these figures and calculations for the 20 counties with the highest resulting Hail EALs for state facilities for each county.

COUNTY	Value of State Facilities in County (Exposure)	X	Hail Annual Frequency	X	Hail HLR (buildings)	=	Hail EAL (State Facilities)
Johnson	$7,507,480,321	X	4.4819	X	0.0000425	=	$ 1,428,871
Story	$4,463,443,063	X	6.4332	X	0.0000050	=	$ 142,362
Black Hawk	$1,922,472,605	X	5.4544	X	0.0000069	=	$ 72,372
Mills	$281,399,500	X	7.1683	X	0.0000340	=	$ 68,559
Lee	$376,742,504	X	3.7054	X	0.0000364	=	$ 50,776
Polk	$1,903,705,687	X	6.2497	X	0.0000036	=	$ 42,406
Page	$191,041,938	X	6.3437	X	0.0000340	=	$ 41,191
Buchanan	$220,398,229	X	5.0701	X	0.0000368	=	$ 41,167
Webster	$160,152,423	X	4.2549	X	0.0000422	=	$ 28,740
Boone	$337,582,685	X	6.4261	X	0.0000101	=	$ 21,959
Calhoun	$65,328,605	X	5.9844	X	0.0000523	=	$ 20,460
Hardin	$82,417,827	X	6.1565	X	0.0000379	=	$ 19,227
Jasper	$126,811,069	X	6.0420	X	0.0000139	=	$ 10,638
Des Moines	$41,636,848	X	3.9865	X	0.0000620	=	$ 10,288
Monona	$35,386,613	X	6.7225	X	0.0000416	=	$ 9,893
Marshall	$281,773,144	X	6.3481	X	0.0000050	=	$ 8,959
Henry	$214,282,446	X	4.0517	X	0.0000093	=	$ 8,113
Cherokee	$135,314,325	X	6.4436	X	0.0000089	=	$ 7,787
Delaware	$28,976,328	X	4.7045	X	0.0000425	=	$ 5,794
Lucas	$51,610,093	X	5.2776	X	0.0000187	=	$ 5,105

[150] NRI's methodology may be found in *National Risk Index Technical Documentation, November 2021*, or at http://www.fema.gov/sites/default/files/documents/fema_national-risk-index_technical-documentation.pdf

The Lightning EALs are calculated for state facilities in each county in a similar manner as for Hail above. This next chart shows how the EALs for Lightning are derived for the 20 counties that ended up having the highest Lightning EALs for state facilities for each county.

COUNTY	Value of State Facilities in County (*Exposure*)	X	Lightning Annual Frequency	X	Lightning HLR (buildings)	=	Lightning EAL (State Facilities)
Johnson	$7,507,480,321	X	68.855	X	0.0000000481	=	$ 24,882.69
Story	$4,463,443,063	X	70.034	X	0.0000000514	=	$ 16,057.89
Black Hawk	$1,922,472,605	X	73.770	X	0.0000000489	=	$ 6,934.51
Polk	$1,903,705,687	X	77.345	X	0.0000000144	=	$ 2,113.99
Lee	$376,742,504	X	79.654	X	0.0000000521	=	$ 1,564.06
Mills	$281,399,500	X	73.450	X	0.0000000647	=	$ 1,337.44
Marshall	$281,773,144	X	71.907	X	0.0000000470	=	$ 951.52
Buchanan	$220,398,229	X	72.288	X	0.0000000512	=	$ 816.19
Pottawattamie	$198,902,571	X	72.752	X	0.0000000316	=	$ 457.83
Jones	$197,339,179	X	69.493	X	0.0000000280	=	$ 384.40
Henry	$214,282,446	X	72.299	X	0.0000000242	=	$ 374.60
Page	$191,041,938	X	73.078	X	0.0000000206	=	$ 287.57
Scott	$127,333,001	X	68.383	X	0.0000000322	=	$ 280.42
Boone	$337,582,685	X	71.476	X	0.0000000107	=	$ 259.06
Appanoose	$44,024,398	X	90.071	X	0.0000000653	=	$ 258.90
Hardin	$82,417,827	X	66.691	X	0.0000000462	=	$ 254.18
Webster	$160,152,423	X	75.273	X	0.0000000206	=	$ 248.28
Decatur	$30,674,063	X	75.551	X	0.0000000701	=	$ 162.55
Cedar	$44,416,862	X	68.042	X	0.0000000424	=	$ 128.29
Dubuque	$78,482,456	X	63.724	X	0.0000000236	=	$ 118.22

Note that for both lists above (Hail EALs and Lightning EALs), the first three counties are ranked the same: Johnson, then Story, then Black Hawk. These counties are also the top three in terms of total exposure, i.e. total value of state-owned facilities in the county. They are also the locations of the three state public universities (University of Iowa in Johnson County, Iowa State University in Story County, and University of Northern Iowa in Black Hawk County). Note also that the top 6 counties of both lists are the same.

3.5.10. Earthquakes

The vulnerability of state-owned or -operated facilities to the earthquake hazard is determined in the same way as it was for severe winter storms, tornado/wind, and hail and lightning. The Expected Annual Loss (EAL) will be calculated for each county, using the same approach as used by FEMA's NRI[151]. The NRI calculates EAL by multiplying exposure by annualized frequency and historic loss ratio (HLR). We just need to use the value of state facilities (and only state facilities) for the exposure component in the formula to calculate EAL. For the components of annual frequency and historic loss ratio (HLR), we can use the

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[151] NRI's methodology may be found in *National Risk Index Technical Documentation, November 2021*, or at http://www.fema.gov/sites/default/files/documents/fema_national-risk-index_technical-documentation.pdf

same figures that NRI used for the Earthquake hazard in the NRI. These figures are determined for each county. So, using the sum values of state facilities in each county (for Exposure), and NRI's values for Earthquake Annual Frequency (Freq) and Earthquake HLR for each county, Earthquake EALs for state facilities for each county are calculated. The following chart illustrates these figures and calculations for the 20 counties with the highest resulting Earthquake EALs for state facilities for each county.

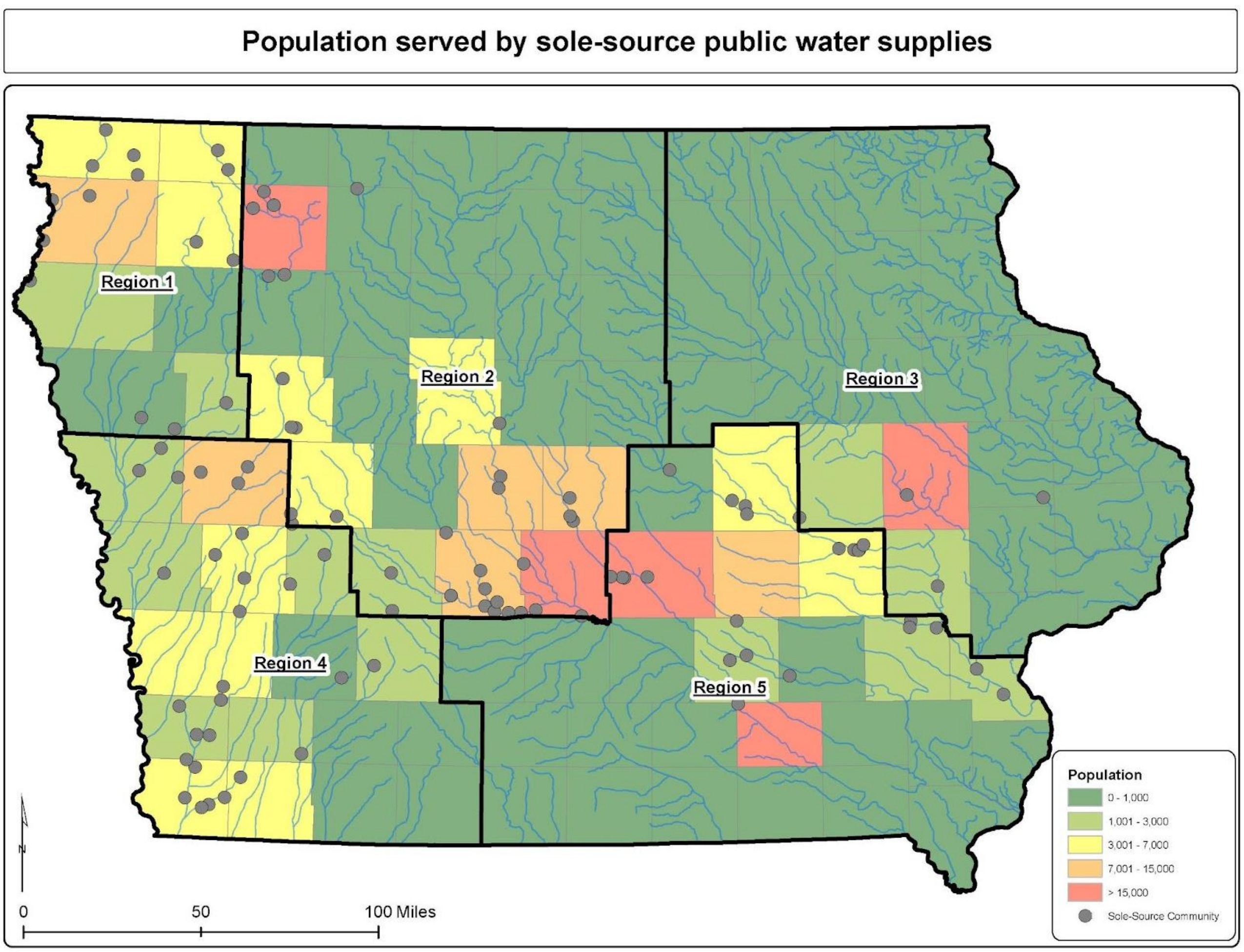
COUNTY	Value of State Facilities in County (*Exposure*)	X	Earthquake Annual Frequency	X	Earthquake HLR (buildings)	=	Earthquake EAL (State Facilities)
Johnson	$7,507,480,321	X	0.0002463	X	0.01675	=	$ 30,973.06
Story	$4,463,443,063	X	0.0001898	X	0.01675	=	$ 14,193.82
Black Hawk	$1,922,472,605	X	0.0001998	X	0.01675	=	$ 6,435.37
Polk	$1,903,705,687	X	0.0001423	X	0.01675	=	$ 4,538.59
Lee	$376,742,504	X	0.0003789	X	0.01675	=	$ 2,391.34
Henry	$214,282,446	X	0.0003735	X	0.01675	=	$ 1,340.68
Boone	$337,582,685	X	0.0001653	X	0.01675	=	$ 934.65
Webster	$160,152,423	X	0.0003131	X	0.01675	=	$ 839.97
Marshall	$281,773,144	X	0.0001725	X	0.01675	=	$ 814.30
Scott	$127,333,001	X	0.0003490	X	0.01675	=	$ 744.29
Buchanan	$220,398,229	X	0.0001887	X	0.01675	=	$ 696.58
Jones	$197,339,179	X	0.0001730	X	0.01675	=	$ 571.82
Mills	$281,399,500	X	0.0001086	X	0.01675	=	$ 512.03
Page	$191,041,938	X	0.0001388	X	0.01675	=	$ 444.27
Pottawattamie	$198,902,571	X	0.0001251	X	0.01675	=	$ 416.81
Linn	$121,004,328	X	0.0001838	X	0.01675	=	$ 372.53
Jasper	$126,811,069	X	0.0001432	X	0.01675	=	$ 304.17
Des Moines	$41,636,848	X	0.0003804	X	0.01675	=	$ 265.33
Jefferson	$41,171,225	X	0.0003438	X	0.01675	=	$ 237.10
Muscatine	$38,866,288	X	0.0003640	X	0.01675	=	$ 237.00

Notice once again the first three counties are also the top three in terms of total exposure, i.e. total value of state-owned facilities in the county. These are the locations of the three state public universities (University of Iowa in Johnson County, Iowa State University in Story County, and University of Northern Iowa in Black Hawk County). The fourth county on the list above is Polk County, the location of the state capital, and the fourth in terms of total exposure. The overwhelming exposure value (value of state facilities) in those first four counties negates any influence from annual frequency. But, starting with the fifth-ranked county, Lee, as well as the sixth, Henry, the frequency/probability of earthquake exhibits its influence on the EAL calculation. Lee and Henry counties are among the top five counties in terms of earthquake frequency and probability of shaking that could cause damage. The other counties in the top five for earthquake frequency and probability are Des Moines, Louisa and Muscatine counties. All five of these counties are in the southeast corner of the state. Among the state facilities in these counties that may be considered more critical are a communication tower and a residential correctional facility of the 8th Judicial District. The following chart shows the number of other critical facilities in these five counties.

County	Number of State Facilities in Counties with Highest Earthquake Frequency/Probability	# Utility Facilities	# Medical Facilities	# Residential Facilities	# Brine/Salt Storage Facilities
Des Moines	26	1		1	4
Lee	38	1		10	5
Henry	83	5		18	5
Louisa	9				
Muscatine	50	2	1	3	6

3.5.11. Drought and Excessive Heat

The last two natural hazards to consider in relation to the vulnerability of state facilities are Drought and Excessive Heat. Because of the nature of these hazards, damage to the physical facility is not as much of a concern as is the impact of drought or heat to the employees that work in a facility or residents who live there. As discussed in section 3.3.1 on drought, of particular concern are areas that rely on a single source for water with the water supply being heavily influenced by drought (like a river, or shallow well). The following map shows such areas.



The operation of State facilities that are served by such water supplies would be the state facilities most vulnerable to drought or heat. The following chart shows several types of state facilities there are in cities served by a sole-source public water supply (storage and open air buildings have been excluded, as their operation would generally not be affected). As medical facilities are relied upon for health care, state medical facilities are of special concern. Also, state residential facilities would be especially vulnerable because people live in these facilities that are at risk of losing water due to drought.

State Facilities Supplied by a Sole-source Water System		
County & Facility Type	**City**	**Number**
AUDUBON		
Military training	Audubon	3
BOONE		
Administrative Offices	Boone	2
Animal Facility	Boone	1
Greenhouse	Boone	1
Lodge	Boone	4
Maintenance	Boone	3
Military Training	Boone	10
Office space	Boone	2
Research Lab	Boone	2
Residence	Boone	2
Restroom	Boone	1
CARROLL		
Office space	Denison	1
CLAY		
Maintenance	Spencer	1
Medical clinic	Spencer	1
Military Training and Operations	Spencer	4
Office space	Spencer	6
CRAWFORD		
Maintenance	Denison	1
Military Training and Operations - Building	Denison	3
Office space	Denison	1
DALLAS		
Office space	Adel	1
Maintenance	De Soto	1
FREMONT		
Maintenance	Sidney	1
GUTHRIE		
Boat house	Guthrie Center	1
Cabin	Guthrie Center	8
Concession	Guthrie Center	3
Lodge	Guthrie Center	2
Maintenance	Guthrie Center	3
Office space	Guthrie Center	2
Residence	Guthrie Center	5
Restroom	Guthrie Center	7

State Facilities Supplied by a Sole-source Water System		
County & Facility Type	**City**	**Number**
Shower	Guthrie Center	2
IDA		
Maintenance	Ida Grove	1
JASPER		
Maintenance	Colfax	2
Academic classroom and office	Newton	1
Greenhouse	Newton	1
Jail	Newton	10
Maintenance	Newton	3
LINN		
Academic Classroom and Offices	Cedar Rapids	1
Maintenance	Cedar Rapids	1
medical clinic	Cedar Rapids	5
Office space	Cedar Rapids	19
Residence	Cedar Rapids	3
Rest area	Cedar Rapids	4
LOUISA		
Concession	Wapello	1
Office space	Wapello	4
LYON		
Maintenance	Rock Rapids	1
MADISON		
Maintenance	Van Meter	1
Residence	Van Meter	1
Restroom	Van Meter	1
MAHASKA		
Boat house	Oskaloosa	1
Concession	Oskaloosa	2
Maintenance	Oskaloosa	2
Office space	Oskaloosa	3
Office space	Oskaloosa	1
Residence	Oskaloosa	1
Restroom	Oskaloosa	5
Shower	Oskaloosa	2
PAGE		
Concession	Shenandoah	2
Office space	Shenandoah	1
POLK		
Maintenance	Carlisle	1
Maintenance	Grimes	1
Office space	Grimes	1
Business	Mitchellville	1

State Facilities Supplied by a Sole-source Water System		
County & Facility Type	**City**	**Number**
Concession	Mitchellville	1
Jail	Mitchellville	7
Pump	Mitchellville	1
Rest area	Mitchellville	5
SAC		
Maintenance	Early	1
Shop	Early	1
SHELBY		
Cabin	Harlan	2
Maintenance	Harlan	2
Office space	Harlan	1
Office space	Harlan	2
Residence	Harlan	1
Restroom	Harlan	8
shop	Harlan	1
Shower	Harlan	1
STORY		
Maintenance	Huxley	1
Animal Facility	Nevada	6
Office space	Nevada	1
Research Lab	Nevada	3
Residence	Nevada	1
TAMA		
Maintenance	Tama	1
WARREN		
Restroom	Carlisle	2