Methodology Document
Climate Liability Spatial Analysis
Conservation Law Foundation
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New England at Risk: Hazardous Sites and Climate Change

Across New England, hazardous sites (both those that are federally regulated, such as Superfund sites, as well as those that aren't, like municipal solid waste landfills) pose threats to the communities they are in. At the same time, climate change is exacerbating environmental hazards and natural disasters such as flooding from sea level rise and more intense storms or wildfires. This project sought to map and communicate on the threats that counties across New England face when hazardous sites are at risk from climate change impacts. This analysis considers three factors: the threat from the sites themselves and the hazardous or toxic materials they contain, how vulnerable a particular area is to climate change impacts including flooding, heat, and wildfires, and how vulnerable a particular community is based on its demographics. The research question at the core of this analysis is: *Where are people and communities in New England the most at risk from threats posed by climate change impacts jeopardizing existing waste and hazardous or toxic sites?* This information is aggregated at the county level and ultimately reflects a relative risk category for each county that is comparable across the region. This information is presented via an Esri StoryMap.

We combined data for climate change impacts (wildfire risk, flood risk, and extreme heat) with the CDC's Social Vulnerability Index to create a vulnerability score for each county, and combined this with the hazard data (analyzed as number of hazardous sites per person per square mile for each county). Climate risk, social vulnerability, and hazardous site scores were multiplied to create a final score and were assigned to risk categories. All factors were weighted equally except for National Priorities List (NPL) Superfund sites, due to their status as national priorities and potential higher risk.

Data

We used data that were publicly available for the entire region so as to be comparable in creating the relative risk rating. Where possible we used climate data that were forward-looking. Climate impacts were chosen based primarily on the following citation: Maco B, Bardos P, Coulon F, et al. Resilient remediation: Addressing extreme weather and climate change, creating community value. *Remediation*. 2018;29: 7–18. https://doi.org/10.1002/rem.21585

The datasets and processing approaches are described below, and the table that follows includes source links.

Climate Change Data

Climate change metrics included wildfire risk, flood risk, and extreme heat. As stated above, because the goal of this study was to reflect risk across the region and our analysis was aggregated to the county level, there were some limitations on datasets for climate risks.

<u>Wildfire risk</u> data were obtained from the US Forest Service's "Wildfire Risk to Communities: Spatial datasets of landscape-wide wildfire risk components for the United States" dataset and uses the Mean Burn Probability (aka wildfire likelihood) variable from the County Summary table, reflecting the arithmetic mean of the annual burn probability for each county. Risk is based on vegetation and other landscape characteristics; see more on the methodology in the link provided in the table of data sources. These data reflect wildfire risk at the time of the analysis and are not projected to account for future changes in weather patterns, landscape or vegetation, etc.

Extreme heat data were taken from the Union of Concerned Scientists' report "Killer Heat in the United States" which uses downscaled data from the fifth Coupled Model Intercomparison Project (CMIP5). This dataset includes days per year with a heat index above 90 degrees Fahrenheit for three time frames: historic (1971-2000), midcentury (2036-2065), and late century (2070-2099). These data are projected based on three scenarios: no action, slow action, and rapid action. We used the no action scenario and subtracted the historic values from the midcentury values to reflect a projected increase, if following a business as usual approach, in days over 90 degrees by the midcentury timeframe for each county.

Flood risk data were obtained from the First Street Foundation's Flood Factor analysis. This includes riverine and coastal flooding and accounts for precipitation, sea level rise, and storm surge. Additionally, these are projected data that account for climate change rather than being based purely on historic data. The First Street Foundation analyzes flood risk on a per property-level basis for commercial and residential properties, and is based on a location's "history and geographic information, such as elevation, climate, changes in the environment, proximity to water, and adaptation measures" (Flood Factor methodology). We used First Street Foundation's average risk score for each county, which takes the average of the individual property scores across the county. Our approach results in some masking of location specific effects such as along the coast, and can make some counties appear more or less at risk overall than when considering these specific locations. Given these limitations, this data should not be used to determine the flood risk for specific properties within a county. Some municipalities, neighborhoods, or properties may be at a higher risk of flooding than the county-level score suggests.

Social Vulnerability

We used the CDC/ATSDR's Social Vulnerability Index to reflect the vulnerability of a county to a disaster. The Social Vulnerability Index (SVI) uses 15 variables from the 2018 US Census (the most current data available for the 2020 SVI): Socioeconomic Status (Below Poverty, Unemployed, Income, No High School Diploma); Household Composition & Disability (Aged 65 or Older, Aged 17 or Younger, Civilian with a Disability, Single-Parent Households); Minority Status & Language (Minority, Aged 5 or Older who Speaks English "Less than Well"); Housing Type & Transportation (Multi-Unit Structures, Mobile Homes, Crowding, No Vehicle, Group Quarters). We downloaded county-level data for the entire US, meaning that counties are ranked against all other counties in the country.

Hazardous Site Data

Hazardous sites include Superfund sites, certain RCRA facilities, and municipal solid waste landfills. Overall we included 2,933 hazardous sites across New England in our analysis. Individual counts of each site type are provided below. Note that some sites are labelled as multiple site types. More information about each of the site types is available in the source links provided in the table.

Superfund site data were obtained from the US EPA's Facility Registry Service (FRS) geodatabase as point data. We included all active, deleted, and proposed Superfund sites (including federal and nonfederal sites and those listed on the National Priorities List sites as well as not). Even sites that have been remediated and removed from the National Priorities List (NPL) may still have contaminants present, and climate change impacts may damage remedial solutions such as caps. Additionally, proposed sites are ones where at least some hazardous material is known to be present and thus still pose a risk to surrounding communities. Sites that are currently on the NPL were counted twice in the scoring methodology and therefore are weighted higher, given that these are sites identified by the EPA as being national priorities for cleanup and therefore likely pose the greatest risk. We included a total of 905 Superfund sites in our analysis, 179 of which are NPL sites.

RCRA facilities were also obtained from the US EPA's Facility Registry Service (FRS) geodatabase. We included Large Quantity Generators (LQGs); Treatment, Storage, Disposal facilities (TSDs), and selected facilities labelled as "Other Hazardous Waste" (namely wastewater treatment plants and landfills). There are many more RCRA facilities across New England and the country that are not included in our analysis, but we selected these sites based on their potential for handling the largest amount of hazardous material and therefore presenting the greatest risk. We included a total 1,947 sites in our analysis.

Landfill data were downloaded from the EPA's Landfill Methane Outreach Program (LMOP) database. This reflects municipal solid waste (MSW) landfills, many of which are not included in the Superfund or RCRA programs since those programs only deal with hazardous waste as federally defined. We downloaded location data for MSW landfills across New England from the EPA's Landfill Methane Outreach Program (LMOP) database and included both active and closed landfills. We included 128 active and closed MSW landfills in our analysis.

The table below summarizes the data and provides links to the sources. The Geoprocessing & Scoring Approaches section further describes the processing and analysis of these variables.

	Source	**Data type**	**Links**	**Notes & Reasoning**
Hazardous/Toxic Sites				
Superfund Sites	EPA - FRS Geodatase download	Points	https://www.epa.gov/frs/geospatial-data-download-service	Includes current, proposed, deleted, and other non-NPL sites. Proposed and deleted sites both are likely to still contain dangerous contaminants, and can be disturbed by climate impacts (Maco et al. 2018).
RCRA Sites - Large Quantity Generators; Treatment, Storage, and Disposal facilities; and Other Hazardous Waste Activities filtered for wastewater treatment plants and landfills	EPA - FRS Geodatabase download	Points	https://www.epa.gov/frs/geospatial-data-download-service	This includes chemical producers, pharmacies, landfills, wastewater treatment plants, and more.
MSW Landfills	EPA LMOP (Landfill Methane Outreach Program)	Tabular (coordinates / points)	https://www.epa.gov/lmop/project-and-landfill-data-state	Hazardous and ash disposal landfills are mostly captured under the RCRA categories described above; this dataset captures MSW landfills
Climate Change				
Flood risk	First Street Foundation	Tabular (risk score for each county)	https://firststreet.dev/register - data were version 1.3 downloaded via the file called County_level_risk_FEMA_FSF_v1.3.csv	Includes riverine and coastal flooding; accounts for precipitation, sea level rise, storm surge
Wildfire	USFS	Tabular (mean burn probability for each county)	https://www.fs.usda.gov/rds/archive/Catalog/RDS-2020-0016 - "data publication support files" download link	Average burn probability (aka wildfire likelihood) for each county. "The [average, for the county data we're using] annual probability of wildfire burning in a specific location. Referred to as Wildfire Likelihood in the Wildfire Risk to Communities web application."

Heat	CMIP (the World Climate Research Programme's Coupled Model Intercomparison Project) via Union of Concerned Scientists	Tabular	https://www.ucsusa.org/resources/killer-heat-united-states-0	Projected number of days annually above 90 degrees (for 2036 – 2065) under a business as usual scenario. We subtracted historic days from midcentury days to reflect projected increase in days over 90
Community Vulnerability				
Social Vulnerability Index (SVI)	CDC/ATSDR	Shapefiles	https://www.atsdr.cdc.gov/placeandhealth/svi/index.html	Includes 15 Census variables to indicate the vulnerability of a county and the county's ability to withstand or recover after disaster
New England Counties				
Counties	US Census (TIGER/Line geodatabase)	Shapefiles	https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.2020.html	

Geoprocessing and Scoring Approaches

All spatial analysis was done using ArcGIS Pro 2.8. Additional analysis was conducted using Microsoft Excel.

County shapefiles were clipped to New England counties. Tabular data (i.e. all climate values) were joined to county polygon shapefiles using GEOID attributes. All hazard data are vector point data or were converted to point data, and were combined into one layer. Using Excel we checked for and removed duplicates as some sites were included in multiple datasets (i.e. both in the LMOP and RCRA databases). We used the Summarize Within tool to count points within each county polygon and one-mile buffers were created around all hazard points so that points were also counted where these buffers crossed county boundaries. Sites that are currently on the National Priorities List were counted twice to reflect their relative higher risk.

The Scoring section below describes the way scores were obtained for each metric, including the overall score. All values were mapped using Natural Breaks (Jenks) in ArcGIS Pro Version 2.8. This approach categorizes values based on natural groupings within the data. Risk categories for all values including the overall score were assigned based on the Natural Breaks classifications.

Scoring

In order to obtain values that were comparable on the same scale, all metrics were converted to a value between 1 and 10. This was done by dividing the scores for each metric into 10 brackets with the highest score as the maximum and the lowest score as the minimum. The range is then divided by 10 and a score from 1-10 was assigned.

Climate Score

The climate score is calculated as follows:

- For each climate risk (i.e. wildfire, temperature, flood risk), the scores for each county are recalculated out of 10. This was done by dividing the scores into 10 brackets with the highest score as the maximum and the lowest score as the minimum. No counties had a score of 0. The range is then divided by 10 and a score from 1-10 was assigned.

- The overall Climate score is an average of the wildfire, temperature, and flood risk scores.

Community Score
This is the score from the CDC's Social Vulnerability Index.

- These scores were refactored to create scores from 1-10 following the same methodology as for the Climate Score described above. The SVI is the only score in this component. No counties had a score of 0.

Hazard Score
The Hazard Score was calculated by multiplying the number of hazardous sites in each county by the population density (people per square mile) of the county. This was done to reflect the greater potential risk posed by sites in densely populated areas. This value was then refactored to a score out of 10 according to the same methodology described above for the other metrics. One county (Grand Isle, VT) had 0 hazardous sites and thus received a hazard score of 0.

Equations:
The Climate Score and the Social Vulnerability Score were averaged to create an overall vulnerability score out of 10. This was then multiplied by the Hazard Score to create an overall score. These scores ranged from 2 (Sagadahoc County, ME) to 75 (Suffolk County, MA). Grand Isle, VT had an overall score of 0 due to having no hazardous sites in the county.

[number of hazards] * [county population density] = Hazard Score

[wildfire risk score + flood risk score + days over 90 degrees] / 3 = Climate Score

[SVI Score + Climate Score] / 2 = Vulnerability Score

[Vulnerability Score * Hazard Score] = Overall Risk Score

Limitations & Future Research
This project examines relative risk at the county level across New England. The county level is a high-level assessment and therefore can smooth out the risk levels of specific sites and locations. This has the potential to make some counties appear more or less at risk than one might expect or indeed than the data might actually indicate. Counties were chosen as the level of analysis due to limitations in data availability at more granular levels, and also because of the ultimate purpose of this project as a communication tool rather than as a site-specific analysis.

There are limitations inherent in the data chosen as well. The wildfire, flood risk, and heat data are all county-level averages of values across the entire area which hides location specific extremes. The flood data also is limited in that it reflects flood risk to commercial and residential properties but exclude other kinds of buildings. This leaves out flood risk to other types of properties such as industrial, many of which may be located on the coast or in areas at risk of flooding due to the importance of water routes for historic and present-day production and trade. It also does not reflect concentrated risks in certain locations within a county nor does it provide information about the site-specific flood risk for hazardous sites within the county. The Social Vulnerability Index is the most recently available version but relies on 2018 Census data. This is particularly challenging given the Covid-19 pandemic; social vulnerability data will most likely look drastically different given the equity impacts of the pandemic. The SVI also doesn't reflect existing exposure to pollutants emitted from the sites in question, which would already be impact the health of the surrounding communities.

For future research, a more fine-grained analysis is recommended in order to understand the potential threats from climate impacts to individual sites. This could include a geospatial approach which could identify precisely where hazardous sites intersect with climate risks, and evaluate sites on an individual level or at more granular levels such as by Census tract or block group. Future research could also expand the definition of "hazardous sites" - those chosen here reflect a broad range of waste sites and facilities generating hazardous waste and materials, but don't include all potentially hazardous or toxic sites. Future research could include an examination of other sites with the potential for human and environmental health impacts, such as those reporting through the EPA's Toxic Release Inventory (TRI) program, or a larger number of RCRA facilities than are included here. Research could also take into account additional information on hazardous sites such as what kind of material is being handled at the site (i.e. what kind of pollutants). Finally, research could include expanded community metrics such as social infrastructure, health criteria, or other factors which could make a community more or less vulnerable or pose a greater risk from the damage of a nearby hazardous site.