Predicting Environmental Health Risks for Post-Disaster Recovery

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Table of Contents

Executive Summary

Major disasters, and other catastrophic incidents result in adverse health outcomes that have been attributed to environmental exposure to hazards released from the built environment. While some hazards may be normally geographically bounded, during a disaster, hazardous substances can spread to surrounding areas. This creates complex challenges for emergency managers, disaster survivors, and communities in understanding how to protect against exposure to environmental health hazards during and after a disaster. Data on environmental hazards exist, but disparate and disconnected sources make analyzing it difficult. These barriers also limit the ability to target additional time-critical data collection needs to understand the actual versus potential hazards in areas of higher risk, guide effective and targeted public health messaging, approximate possible hazard exposures after the fact to support patient care and health registries, and deliver recommended training and health protections for at-risk response and recovery workers, including the usage of personal protective equipment. In addition to considerations for hazards that may stem from the built environment, there is an equally robust array of data to describe the extent to which the population may be more or less susceptible to environmental health hazards. In particular, individuals with access and functional needs, chronic disease, and limited ability to leave a hazardous area all are considered to be more vulnerable to post-disaster health risks.

This Patient Centered Outcomes Research Trust Fund (PCORTF) sponsored project attempts to address the shortcomings in knowledge, data barriers, and limitations. The goals of the project are to (1) build a data platform in which state and county level healthcare needs and disaster-related information can be tracked over time and used to predict needs in future disasters and (2) pilot an evaluation and assessment of vulnerabilities to known hazards in our built environment and their adverse effects on public health outcomes after a disaster (predictive modeling).

This pilot integrates multiple publicly available databases into a single geospatial platform that can be used to guide emergency management decision-making in a crisis by anticipating areas of concentrated resource needs and informing the public about their potential vulnerability to environmental health hazards. The platform can also be used by patient-centered outcomes researchers to correlate post-disaster environmental health hazard exposures with secondary and long-term negative health consequences.

The result of the model is a **static** view of the location of known environmental hazards and contaminants and is not a predictor of actual exposure to any single substance during a disaster or during the response and recovery**.** It uses the best publicly available data at a resolution useful for analysis below the county-level and attempts to balance the need for high resolution, local datasets and datasets with national coverage (but possibly lower resolution). The platform itself provides a baseline framework for evaluating environmental hazards that can be scaled across geographies.

The results from the project are publicly available for viewing through HHS's web map platform, GeoHealth (https://geohealth.hhs.gov/arcgis/home). In addition, an interactive dashboard is available to allow users to view each indicator as well as the composite index.

As a pilot project, the project team has identified a series of recommended next steps to prioritize the future direction and extension of this work.

- **Pilot Recommended Next Steps** include expanding and testing the model for suburban and rural geographies, incorporating additional environmental hazard data, allowing users to define spatial resolution of the model results, and considering the integration of American Community Survey demographic data into the SVI.
- **Exercise/Workshop Recommended Nest Steps** include evaluating the feasibility of incorporating planning workshop recommendations, exploring integration of outputs from existing impact models, and expanding the functionality and display of the results in the GeoHealth Dashboard.
- **Technical Recommended Next Steps** include operationalizing the Toxic Release Inventory and Superfund APIs, translating python script to Python 3, and building in a function to allow users to specify their area of interest

Project Background

Major disasters and other catastrophic events result in unanticipated adverse health outcomes that have been attributed to environmental exposure to hazards released from the built environment. These hazards create complex challenges for emergency managers, disaster survivors, and communities in understanding how to protect against exposure to environmental health hazards during and after a disaster. During a disaster, the first task is to respond to the immediate, emergent lifesaving needs of the people in the affected area, those in areas that are indirectly affected, and emergency responders. While the protection of life and property will be the first priority, effective emergency management and public health officials should also be prepared to address hazards and risks as they unfold, especially in the months and years afterward[1]. Researchers have studied the relationship between the built environment and poorer health outcomes in communities during steady-state conditions for decades, particularly for issues surrounding environmental justice. However, research on the effects of the built environment on public health outcomes during a disaster and in the years following is less robust. Some of the more well publicized and visible negative public health outcomes that *has* garnered significant research are the impacts of exposure to the environment at ground zero in New York City and the Pentagon following the September 11th terror attacks. The consequences of exposure to that environment continue to manifest nearly two decades later.

An integrated platform to provide guidance to anticipate environmental health hazards coupled with social vulnerability (including chronic disease and mobility limitations) and post-incident hazard assessment data, however, does not exist. For example, there are datasets which contain the age of structures, the type of construction, and their location, but do not relate this information to disaster associated health risks presented in building debris with likely hazardous construction materials. These datasets could be evaluated to determine the likelihood for the presence of environmental health hazards like asbestos, lead-based paint, or other hazards common in building construction.

Other critical factors influencing post-disaster health include the vulnerability of a community and high-risk individuals. The Centers for Disease Control and Prevention's Agency for Toxic Substances and Disease Registry (CDC/ATSDR) has data available to public health officials and emergency planners about the adverse health outcomes from exposure to natural and man-made hazardous substances and information exists on facilities handling such materials, but little information is available to help officials and planners anticipate hazards during the preparedness, mitigation, response, and recovery phases of emergency management.

This gap in knowledge, data limitations, and barriers to connect disparate datasets when required, limits the ability to:

- Target additional time-critical data collection needs to understand the actual versus potential hazards or contamination in impacted high-risk areas;

[1] Goldman, L., & Coussens, C. (2007). Environmental public health impacts of disasters: Hurricane Katrina: Workshop summary. Washington, D.C.: National Academies Press.

- Guide effective and targeted public health messaging;
- Approximate possible hazard exposures after the fact to support patient care and health registries; and
- Deliver recommended training and health protections for at-risk response and recovery workers; including the usage of personal protective equipment.

This Patient Centered Outcomes Research Trust Fund (PCORTF) sponsored project attempts to address the shortcomings in knowledge and data barriers and limitations in two components:

1. Build a data platform in which state and county level healthcare needs and disaster-related information can be tracked over time, and used to predict needs in future disasters; and,
2. Pilot an evaluation and assessment of vulnerabilities to known hazards in our built environment and their adverse effects on public health outcomes after a disaster, herein after referred to as "predictive modeling."

Together, the data platform and predictive modeling will enable research in a crisis, helping decision makers deploy the right medical expertise and supplies and improve patient outcomes through evidence-based care. In addition, this project will provide the broader research community with a depth of information on disaster healthcare utilization and environmental hazard evaluation that has not previously been available. These data can be used to compare interventions and outcomes in a disaster, analyze and improve response strategies, identify needs and trends for long-term recovery, and track the long-term health consequences of a disaster. Using this tool, researchers would also have the capacity to improve future modeling capabilities, sampling techniques, and other applied research used in post-disaster settings. The tool could serve as an important baseline to stimulate future research and subsequent support for real-world application.

There presently does not exist a tool that considers the built environment, post-disaster impact assessments, known environmental health hazards, and how the confluence of those factors may impact worker, volunteer, and first responder health outcomes.

With disasters, such as the World Trade Center attack, hurricanes Katrina, Sandy, Harvey, Maria, and Irma, and recent California Wildfires, we have observed the release of millions of pounds of toxins,[2] [3] including volatile organic compounds, asbestos, untreated sewage, and lead

[2] Necessary Prevention: Toxic Pollution and Natural Disasters. (2019, March 01). Retrieved from http://chej.org/2019/03/01/necessary-prevention-toxic-pollution-and-natural-disasters/

[3] Goldman, L., & Coussens, C. (2007). Environmental public health impacts of disasters: Hurricane Katrina: Workshop summary. Washington, D.C.: National Academies Press.

and other heavy metals into the air, soil, and water. These hazards can come from many sources, including[4]:

- Submerged or exploding industrial plants;
- Releases of liquid fuels, solvents, cleaning fluids, anti-freeze and other toxic chemicals from thousands of crushed vehicles, containers, drums and tanks;
- Wash from flooded subways, roads, parking lots and tunnels;
- Sewage overflows that contaminate watersheds and water supply, as was the case in Puerto Rico.[5] Storm surges can overwhelm infrastructure sending sewage spilling back onto roads, into homes, and directly to surface waterbodies;
- Demolished buildings containing asbestos or developing mold, potentially harming residents as well as response personnel;[6]
- Wildfires that burn plastics, asbestos material, or treated wood produce emissions, including toxic volatile organic compounds and heavy metals that are particularly dangerous for people with asthma or respiratory diseases;[7]
- Fires caused by broken gas mains or lightning can burn unabated and may generate smoke containing particulates such as soot as well as toxic chemicals including dioxins and other air-borne pollutants;[8]
- Farm-related runoff containing fertilizers, pesticides, and herbicides; and
- Exposure to lead and other toxic substances by accidental ingestion of contaminated soil from dirty hands, as well as the breathing of contaminated dust and fumes from burned plastic or cable coatings.

Collectively, disaster related environmental hazards can be categorized as:

- Hazards identifiable pre-disaster (e.g., point specific chemical storage, industrial usage, Superfund sites);
- Hazards typically classified as low risk that become a population level hazard during disaster, but can be more difficult to identify or model pre-disaster (e.g., treated lumber, lead, or asbestos in structures);

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[4] Horkovich, & Nevius. (2017). The Environmental Impact of Hurricanes. Retrieved from http://www.rmmagazine.com/2017/12/04/the-environmental-impact-of-hurricanes/

[5] EPA Hurricane Maria Update, Friday January 5, 2018. (2018, January 05). Retrieved from https://www.epa.gov/newsreleases/epa-hurricane-maria-update-friday-january-5-2018

[6] U.S., Environmental Protection Agency, Office of Enforcement and Compliance Assurance. (2009). Page 5. Retrieved June 13, 2019, from https://www.epa.gov/sites/production/files/documents/guidance-catastrophic-emergency-asbestos-200912.pdf

[7] Polakovic, G. (2018, November 15). California wildfires raise concerns about impacts to environment and health. Retrieved from https://news.usc.edu/151775/california-wildfires-raise-concerns-about-impacts-to-environment-and-health/

[8] Earthjustice. (2019, January 31). The Lessons We Didn't Learn From the Largest Gas Leak in U.S. History. Retrieved June 13, 2019 from https://www.ecowatch.com/natural-gas-leaks-health-california-2615397026.html

- Hazards that could become present because of the conditions of the disaster (e.g., sewage, mold, vector borne diseases), but are not typically present prior to the disaster (but could potentially be modeled with the appropriate data); and
- Hazards that result from human actions during and following disasters (e.g., solid waste collected and stored, possibly resulting in contaminated runoff or concentrated toxicity) that cannot be identified beforehand but could be modeled with appropriate data.

Geographic regions, as well as each disaster type (e.g., flood, wind, seismic, etc.), present unique environmental hazards and health concerns. Some environmental hazards are obvious, such as Superfund contamination sites, while others are less obvious, like asbestos in buildings. In both cases, the hazards are geographically bounded; however, disasters can spread hazardous substances to surrounding areas or expose populations to hazards that were otherwise contained. Data on a variety of environmental hazards exist, but disparate and disconnected sources make analyzing the data difficult. Determining the potential for migration of environmental hazards, risks of exposure, dosing, and adverse responses in the population are also very complex.

Approach to Identify Environmental Hazards

Identifying environmental hazards is a difficult process. There were several works significant in helping to guide the team's understanding of environmental hazards, both in steady state and within the context of disasters, and to frame the project design, identify and prioritize critical datasets, and inform our assessment methodology. These works are listed below and cited throughout this document:

- Institute of Medicine. Environmental Public Health Impacts of Disasters: Hurricane Katrina. Washington, DC: The National Academies Press. 2007
- Nemerow, Nelson Leonard. Environmental Engineering: Prevention and Response to Water-, Food-, Soil-, and Air-borne Disease and Illness. 6th ed. Hoboken: John Wiley & Sins. 2009.
- Skinner, John H. Managing Wastes Produced by Natural Disasters. Solid Waste Association of North America
- Department of Homeland Security. Comprehensive Preparedness Guide (CPG) 201, 3rd Edition. 2018
- Schultz, Jessica. Elliot, J.R. Natural disasters and local demographic change in the United States. Popul Environ. DOI 10.1007/s11111-012-0171-7. 2012
- Watson, J.T. Gayer, M. Connolly, M.A. Epidemics after Natural Disasters. Emerging Infectious Diseases. Vol. 13, No. 1, January 2007

There are five basic questions to consider when identifying environmental hazards.[9]

1. Who and where is at risk?
2. Where do these environmental hazards originate?

[9] EPA. 2017. Conducting a Human Health Risk Assessment. Accessed from https://www.epa.gov/risk/conducting-human-health-risk-assessment. Accessed on August 7, 2019.

3. How might populations become exposed to the environmental hazard(s)?
4. How do individuals respond to an environmental hazard and how is this affected by population and individual factors such as age, race, sex, genetics, and socio-economic factors?
5. How do these concerns change over time?

The first two questions are place-based and can be partially or fully answered depending on data availability and resolution, this will be discussed in more depth later in this report. The remaining questions are more difficult to answer at the scale and scope of this pilot project; however, through a review of the literature and discussions with a technical expert panel, a list of environmental hazards was generated based on several considerations. Hazards that are more common near populations were prioritized over extremely rare hazards. A community may be more vulnerable adjacent to an exotic hazard but is limited to a small number of individuals, in contrast to less hazardous but more common risks found across the U.S. Second, hazards that present potential risks across a broad spatial scale (neighborhood/community wide) were included, versus those that may have limited exposure potential (individual structures).

Disaster type is another consideration when evaluating hazards; however, based on project timeline and data constraints, it was omitted from this assessment. As a result of this pilot project, public health officials will be able to better identify possible hazards and their location in relationship to vulnerable populations. They will also be able to use the information when speaking with other experts and as inputs into existing spatial and non-spatial modeling tools, such as plume models, to understand how hazards may react under different catastrophic scenarios.

Model and Data Limitations

The target geographic resolution for this project is the ZIP code tabulation area (ZCTA), a U.S. Census Bureau geographic unit defined as a generalized areal representation of United States Postal Service ZIP code service areas.[10] In the majority of instances, the ZCTA code is the same as the mailing address ZIP code of the geographic unit. ZCTA was chosen as the target geographic resolution because it can provide a higher resolution result than a county-level analysis while not being so restrictive that data may need to be excluded because of it may not be available at the census block or census tract levels. For larger metropolitan areas, ZCTA can provide enough resolution to show spatial differences at the city scale.

The disaster recovery environmental hazard index evaluates known hazards and their spatial relationships with vulnerable populations and serves as a screening tool. The model produces a static view of the location of known environmental hazards and contaminants and is not a predictor of actual exposure to any single substance during a disaster, or response and recovery.

[10] U.S. Census Bureau (2019). Accessed from https://www.census.gov/programs-surveys/geography/guidance/geo-areas/zctas.html. Accessed on June 6, 2019.

Results are presented as a percentile rank (a relative value on a scale from zero to one) so that a higher than average vulnerability rank in Los Angeles may not be the same for the District of Columbia. The model uses the best publicly available data at a resolution useful for analysis below the county-level. Some datasets were excluded from this analysis because of a lack of data availability or the data resolution was too gross. Further discussion about the limitations of individual datasets can be found in the **Error! Reference source not found.** and **Error! Re ference source not found.** sections of this report. The model attempts to balance the need for high resolution, local datasets and datasets with national coverage (but possibly lower resolution). The model itself provides a baseline framework for evaluating environmental hazards that can be scaled across geographies, but the ability for users to input their own higher resolution datasets is currently limited.

Additional factors constrain the ability to evaluate hazards and adverse health outcomes within the framework. Evaluating adverse health outcomes is highly complex, and attributing outcomes to such environmental hazards is challenging. Examples of variables to consider when evaluating hazards and possible adverse health outcomes include:

- Time and spatial scales of the disaster and exposure to the hazard or contaminant
- Exposure pathways (e.g., inhalation, ingestion, direct or indirect contact)
- Exposure route and the state of the contaminant may change over time (e.g., flood waters receding leaving behind contaminated sediment which could turn to dust)
- Dosage or degree of exposure varies across hazards and contaminants
- Predicting the mixture and interactions between substances during or after a disaster
- Predicting fugitive contaminant storage facilities as a result of a catastrophic event (i.e., the physical structure is relocated as a result of the disaster)

Despite the aforementioned challenges and limitations, it is possible to evaluate known environmental hazards using publicly available datasets. While the tool may not be able to predict with certainty adverse health outcomes during any single event, it should evaluate a degree of vulnerability for geographic areas based on available information before catastrophes.

Evaluating Social Vulnerability

To understand and evaluate potential pre-disaster environmental hazards, we need to understand and identify the demographic profiles of vulnerable populations. Much research has been completed to define and measure vulnerability among populations using demographic data and other measures associated or correlated with increased risk of adverse health impacts, whether from indirect exposure to elements within our everyday built environment, or direct exposure to a chemical or other known hazard. Rather than create a unique social vulnerability index for this project, we sought to leverage an existing index. To this end, we evaluated several existing social vulnerability indices in addition to the CDC's Social Vulnerability Index to compare differences and similarities in demographic variables and approaches to calculating an index. A discussion of the indices we evaluated follows, though we recognize this is not an exhaustive list of available indices, it was useful to understand the range of approaches found in the literature.

Social Vulnerability Index (CDC)

The CDC adapted the Social Vulnerability Index (SVI) database and mapping tool pursuant to the Pandemic and All-Hazards Preparedness Act of 2006. The tool is designed to support disaster management officials in identifying the locations of socially vulnerable populations at the census tract level.[11] The SVI is divided into four domains of demographic characteristics – socioeconomic status, household composition and disability, minority status and language, and housing and transportation. Each domain includes census variables indicative of vulnerability.

Advantages

This data layer has national coverage at the census tract level and uses a simple percentile rank methodology of 15 demographic indicators. Each indicator is included in the downloadable dataset allowing analysts to view and leverage the data for more focused analysis. As a CDC product, its use demonstrates the value of cross agency collaboration.

Limitations

The most recent index available uses 2016 American Community Survey (ACS) population estimates and is updated once every two years. The index is only available at the county or census tract level. There is no API with this dataset.

EJSCREEN (EPA)

A national environmental justice (EJ) mapping and screening tool created by the EPA in 2010 with the most recent version released in 2017, EJSCREEN integrates data from the Census

[11] Flanagan, Barry E.; Gregory, Edward W.; Hallisey, Elaine J.; Heitgerd, Janet L.; and Lewis, Brian (2011) "A Social Vulnerability Index for Disaster Management," Journal of Homeland Security and Emergency Management: Vol. 8: Iss. 1, Article 3.

Bureau, U.S. Department of Transportation, and EPA offices to create EJ indices specific to certain pollutants at the census block level.

Advantages

A national, screening-level look at environmental hazards and vulnerable populations is available at the census block level. EJSCREEN includes linguistic isolation indicators and applies a simple methodology to calculate the index by multiplying the demographic index value with the environmental indicator and population count.

Limitations

The most recent data available is sourced from a number of disparate datasets including the U.S. Census Bureau's American Community Survey 2017 population estimates. Education, linguistic, and age indicators are not included in the index, rather listed as attributes of the tool. Demographic index is limited to two variables (percent minority and percent low-income households). The authors of the index caution there is uncertainty in estimates for small geographic areas.

Wisconsin Heat Vulnerability Index (Wisconsin Department of Health Services)

Created by the Wisconsin Department of Health Services, this index utilizes data related to health, demographics, transportation, and the physical environment to create an indicator of baseline county-level vulnerability for the state of Wisconsin and census tract-level vulnerability for the cities of Madison and Milwaukee.

Advantages

Demographic indicators are similar to CDC's SVI and based on ACS estimates. Social isolation indicators are emphasized. Straightforward z-score methodology allows the index to easily be replicated across geographies.

Limitations

Fewer demographic indicators are captured in this index with particular emphasis on infants and the elderly. This analysis is limited to measure susceptibility to heat-related illness at the county-level.

County Health Rankings (Wisconsin Population Health Institute)

Created by the Wisconsin Population Health Institute, this measure ranks all counties in the U.S. based on health behavior and health outcomes datasets.

Advantages

It combines multiple demographic indicator data from U.S. Census Bureau, CDC, Federal Bureau of Investigation (FBI), the Centers for Medicare & Medicaid Services (CMS), Area Health Resource File, and Dartmouth Atlas of Health Care with national coverage.

Limitations

The majority of datasets contained in the index are only available at the county-level. Methodology is slightly more complex and incorporates measure-specific peer reviewed approaches.

Coastal City Flood Vulnerability Index (Balica, et. al.)[12]

The Coastal City Flood Vulnerability Index integrates hydro-geological, socio-economic, and politico-administrative data to create a measure of exposure, susceptibility, and resilience for nine coastal cities in the U.S.

Advantages

This index incorporates population growth and density of emergency evacuation shelters and hospitals. Other factors contained include community and preparedness indicators.

Limitations

Indicators included in this index are difficult to acquire, with geographic availability limited to nine coastal cities.

Area Deprivation Index (Singh, Gopal K.)[13]

The Area Deprivation Index integrates 21 socioeconomic indicators to approximate the material conditions, social conditions, and relative socioeconomic disadvantage of communities. Indicators were selected on the basis of previous empirical research at the census tract level using 1990 census data.

Advantages

Of the indices reviewed, the Area Deprivation Index contained the second most demographic indicators measured at the census tract level. Similar indicators as used in CDC's SVI.

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[12] Balica, S.F., Wright, N.G., van der Meulen, F. 2012. A flood vulnerability index for coastal cities and its use in assessing climate change impacts. Natural Hazards 64:73-105.
[13] Singh, Gopal K. 2003. Aprea Deprivation and Widening Inequalities in U.S. Mortality, 1969-1998. American Journal of Public Health. Volume 93, Number 7. July 2003.

Limitations

The index would require recalculation with either 2010 census data or 2016 ACS estimates for a more current result. The index uses a principal component analysis (CPA) to determine the weights for each indicator. The weights were then applied to combine the components into a single index. This approach is more complex than other indices we reviewed.

Social Environmental Index

Based on the data availability and limitations considered in the datasets described above, this project sought to build on prior efforts and augment these datasets to incorporate additional data points that can add consideration for other vulnerability factors. In constructing this adapted data set, the project developed the Social Environmental Index. At its core, the Social Environmental Index builds on the demographic variables in other indices were already incorporated in the CDC's SVI. Additionally, after considering the index methodology, it was determined that the CDC's calculation allowed easy integration of additional indicators specific to this project. Demonstrating the usefulness of existing spatial products was also a factor in the determination to use the CDC's SVI as a foundation in this analysis.

To supplement the SVI, six additional datasets were selected on health indicator data and populations with mobility needs. People with mobility needs are at increased risk of exposure to environmental hazards and contaminants after a disaster because they are unable to evacuate without assistance.[14] Populations with limited mobility may be at increased risk of prolonged exposure, compared to more mobile populations, because of their inability to evacuate a disaster area on their own. Nursing homes (or similar long-term care facilities), correctional facilities, homeless shelters, medically dependent Medicare beneficiaries, and the elderly living alone are inherently less mobile and, therefore, were selected for this analysis. Emergency evacuation shelters were also selected for inclusion in the social environmental index because by definition, these shelters will receive people during an emergency and may inadvertently expose them to environmental hazards or contaminants based on the location of the shelter relative to the disaster.

Social Environmental Index Data Sources

The following table provides a description and information on the update cycle of the variables contained in the social environmental index for this pilot project.

[14] Pakjouei, S., Aryankhesal, A., Kamali, M., & Seyedin, S. H. (2018). Experience of people with physical disability: Mobility needs during earthquakes. Journal of education and health promotion, 7, 80. doi:10.4103/jehp.jehp_40_18

Table 1: *List and description of data variables included in the social environmental index.*

Social Vulnerability Index	Integrates 15 data tables from the U.S. Census Bureau to create a measure of community vulnerability in the face of natural disaster and hazard.	CDC (2016)	Every two years
Nursing Home Certified Resident Capacity	Includes facility location and certified capacity as a nation-wide dataset.	CMS (2019)	Unknown
Correctional Facility Capacity	A nation-wide dataset with the location of correctional facilities and their capacity.	HIFLD (2018)	Annually
Homeless Shelters	Location of homeless shelters for the City of Los Angeles and District of Columbia. No national dataset is available.	City Data Portal (Varies)	Varies
Emergency Evacuation Shelter Capacity	Location and capacity of FEMA or the American Red Cross designated emergency evacuation shelters as a nation-wide dataset.	HIFLD (2018)	Annually
Electricity Dependent Medicare Beneficiaries	Nation-wide data on the total number of at-risk electricity-dependent Medicare beneficiaries at the ZIP code level.	emPOWER (2019)	Monthly
Various Health Indicators	Estimated prevalence rates of various health indicators at the census track level for 500 cities across the U.S.	CDC 500 Cities (2018)	None

Social Environmental Index Methodology

The CDC's SVI is available at two geographic scales, the county and census tract. Because the project's target geographic resolution is below the county but higher than census tract, aggregating the SVI from the census tract was required. To aggregate the census block data to the ZIP code tabulation area, the geographic weighted sum was applied where the percent land area of the proportion of any given census tract within a specified ZIP code was used to recalculate the SVI value. Then the sum of the recalculated values for each portion of census tract intersecting the specified ZIP code became the aggregated ZIP code SVI value. Census tracts with no calculated SVI score were treated as zero values rather than -999 to avoid penalizing the new aggregated score.

Disease prevalence rates from the CDC's 500 Cities Project were used as an indicator of community health in this model. It used demographic data to model prevalence rates of health outcomes at the census tract level. The key data sources used for the model were the CDC Behavioral Risk Factor Surveillance System, the Census 2010 population, and the American Community Survey estimates. With this data, a multi-level regression and poststratification method was used to estimate the prevalence rates of disease at the census tract and countylevels. As this is modeled data, it should be emphasized that the prevalence rates used in the social environmental index are estimates and have not been validated in all parts of the U.S. For more information about the methodology used in the CDC 500 Cities estimates visit https://www.cdc.gov/500cities/methodology.htm. Unfortunately, this dataset is limited to the 500 cities in the project; however, it does demonstrate the usefulness of the availability of similar, high resolution health indicator datasets available for the entire country.

Because the CDC 500 Cities Project data is available at the census tract level, it was aggregated to the ZCTA level using the same geographic weighted approach as with the SVI data. To incorporate the six additional variables into the SVI scores, the same percentile ranking methodology was followed that was used to create the SVI. A new social environmental index value was calculated by summing the individual percentile ranks for each variable and then calculating a final percentile rank of the total score.

Results

For both Los Angeles and the District of Columbia, the results of the social environmental index are spatially consistent compared to the original social vulnerability index with minor shifts in the overall index. This is to be expected given the SVI already contained 15 unique variables and census tracts are not perfectly contained within ZIP code tabulation areas. **Figure 1** and **Figure 2** show the distribution of vulnerable populations according to the original SVI (mapped at the census tract level), the original SVI aggregated to the zip code level, and the social environmental index.

In Los Angeles subtle shifts from average to well above average vulnerability were observed along the western edge of the Highway 101 corridor due to higher than average health indicator rates (which are absent from the original SVI). Higher rates of electricity dependent Medicare beneficiaries contributed to this shift as well.

There is an almost clear divide between neighborhoods in the northwest and those in the northeast, southeast and southwest of the District of Columbia in regard to social environmental index. Neighborhoods in the northwest are less vulnerable primarily because of demographics. The results of the social environmental index correlate well with the racial and socioeconomic divide in the city, where wealthier Caucasian residents reside in the northwest and minority populations are concentrated in the other three quadrants of the city. Health indicators, electricity dependent Medicare beneficiaries, homeless shelter count, and percentage of population who are elderly and living alone are the primary drivers of ZCTAs moving from less vulnerable to more vulnerable when comparing the original SVI with the social environmental index.

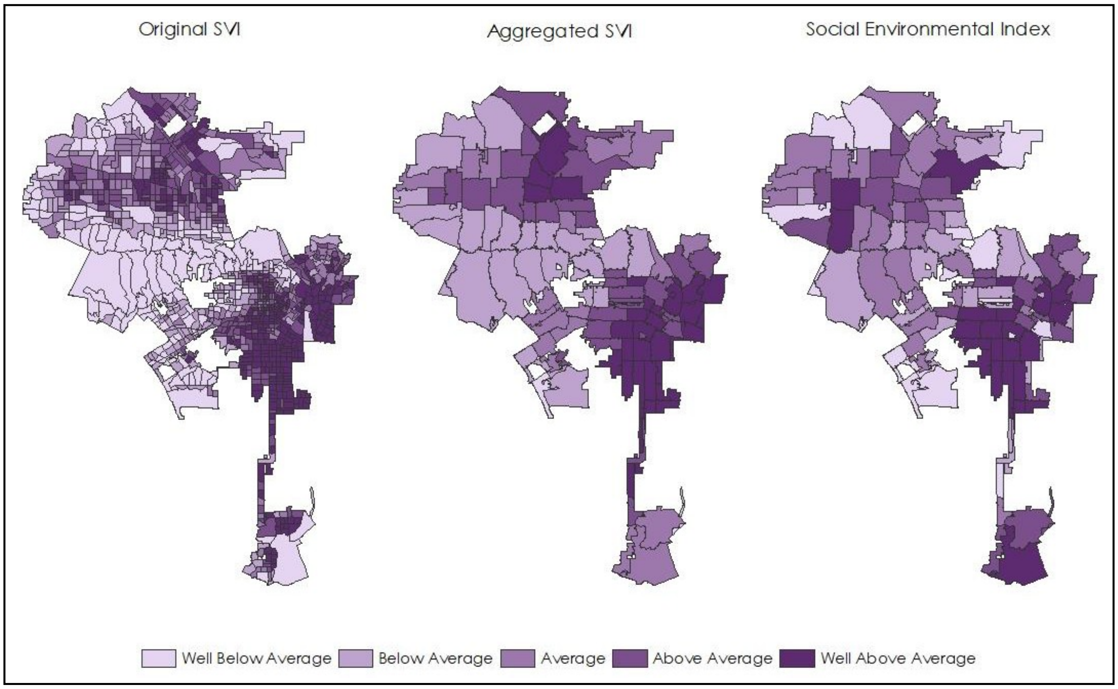

Figure 1*: Comparing (from left to right) the original CDC Social Vulnerability Index mapped at the census tract level, the SVI aggregated to the ZIP code tabulation area, and the final social environmental index for the City of Los Angeles.*

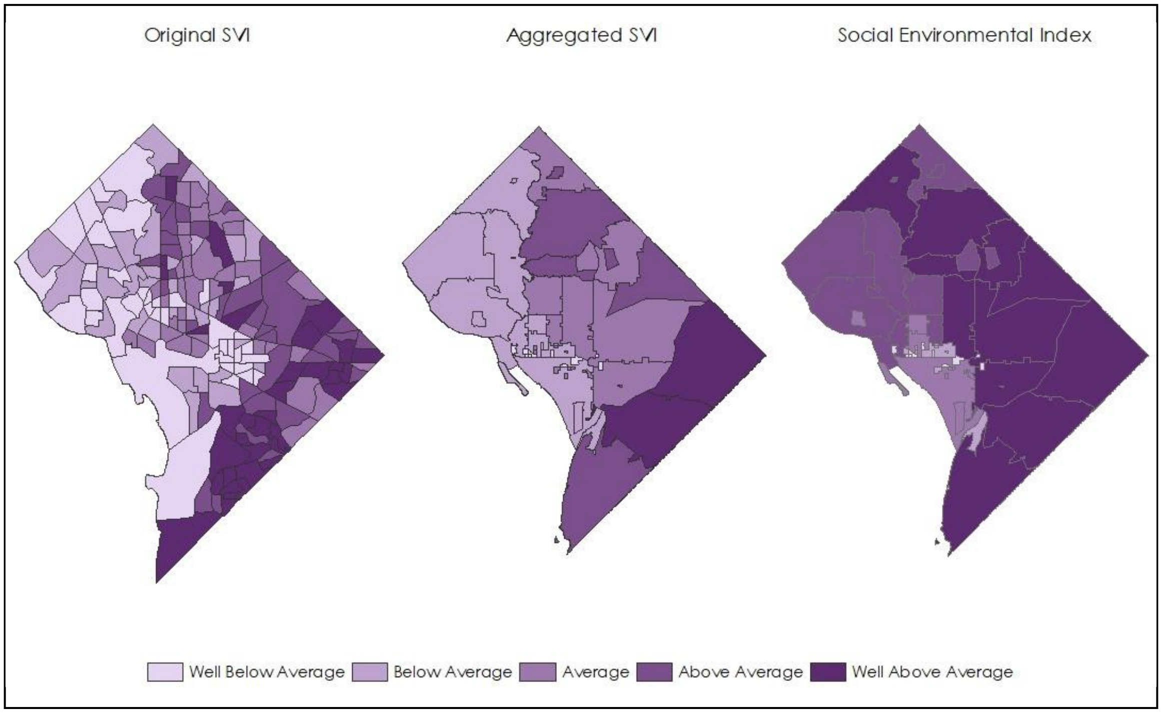

Figure 2: *Comparing (from left to right) the original CDC Social Vulnerability Index mapped at the census tract level, the SVI aggregated to the ZIP code tabulation area, and the final social environmental index for the District of Columbia.*

Evaluating Post-Disaster Built Environment Health Hazards

This pilot attempts to close a gap in methodologies to identify known environmental hazards and the spatial relationship to vulnerable populations, aggregated to a geographic unit useful to support decision-making in emergency preparedness and disaster response and recovery. The list of environmental hazards identified in this report provides a foundation to build an analytical framework to evaluate hazards. Once hazards were broadly defined, appropriate data sources were identified, and a review of existing environmental hazard indices was completed to identify opportunities to recycle or adapt existing analysis methodologies. Two documents in particular guided the approach to using data from the toxic release inventory – the CalEnviroScreen 3.0 and A Visual Data Analysis of the Toxic Release Inventory (Langlois, 2018).[15,16]

CalEnviroScreen 3.0 is a place-based model that characterizes pollution burden and population characteristics using California statewide indicators to evaluate community-scale public health impacts and identify those most burdened by pollution from multiple sources. The California Environmental Protection Agency (CalEPA) and Office of Environmental Health Hazard Assessment (OEHHA) developed this screening tool in an effort to address the gap in methodologies to fully integrate geographic and intrinsic and extrinsic factors into risk assessment. This tool also uses a percentile methodology to assign scores for each indicator, similar to CDC's SVI. One key difference between CalEnviroScreen 3.0 and this pilot project is CalEnviroScreen 3.0 is limited to pollution sources released during steady state conditions. For example, ozone, PM 2.5 concentrations, diesel particulate matter and traffic density are indicators in CalEnviroScreen 3.0 but are excluded from this pilot project.

In Langlois the author highlights the availability of additional chemical release data under the toxic release inventory program beyond the location of registered facilities. This information could be useful in estimating facilities of greater concern which will be discussed further in the methodology section below.

Availability of data on environmental hazards is a major constraint to evaluating indicators. For this project data had to be publicly available through an open data portal or public application programming interface (API). Data resolution had to be useful below the county-level or it was excluded from this pilot because the City of Los Angeles is a sub-unit of Los Angeles County and a county-level dataset would not be useful at our geographic level of analysis. Other data considerations attempt to balance data resolution with geographic coverage to ensure scalability of the model across future geographies. It is understood that detailed data on environmental hazards may only be available at the local level. For example, building inventories to estimate lead and asbestos occurrence in building debris is only available at the local level, and not all jurisdictions have these data. A more detailed discussion about data sources and methodology will follow.

[15] California Environmental Protection Agency (2017). CalEnviroScreen 3.0: Update to the California communities environmental health screening tool.
[16] Langlois, Theodore Charles, "A Visual Data Analysis of the Toxics Release Inventory" (2018). All Theses. 2929. https://tigerprints.clemson.edu/all_theses/2929

Research indicates proximity to environmental hazards can lead to disproportionate health outcomes during steady state conditions.[17] Therefore, proximity is an important indicator in evaluating potential for exposure to a known hazard or contaminant during a disaster when conditions could cause the hazard that would normally be properly contained to be released into the environment.

Due to data availability and project timeline constraints, this pilot does not include an exhaustive list of known environmental hazards, but the methodology discussed below will provide a framework to evaluate and incorporate additional hazards, including locally higher resolution datasets not available at the federal level.

SUPERFUND SITES

The National Priorities List (NPL) contains the most serious uncontrolled or abandoned hazardous waste sites throughout the United States and territories. These sites can be damaged and flooded during disasters, as observed in Texas during Hurricane Harvey where thirteen sites were flooded[18,19,20] and potentially expose humans to chemical hazards, such as those desperately drawing water from the Dorado Groundwater Contamination Superfund site in Puerto Rico in the aftermath of Hurricane Maria.[21]

Not all Superfund sites are considered national priorities by EPA and so do not appear on the NPL. A determination is made about whether a site is placed on the NPL through the Hazard Ranking System (HRS), a numerically based screening system using information from initial limited investigations to assess the relative potential of sites to pose a threat to human health or the environment, as well as additional site assessment. It is the principal mechanism EPA uses to place uncontrolled waste sites on the NPL. The HRS uses a structured analysis approach to scoring sites. This approach assigns numerical values to factors related to risk based on conditions at the site. The factors are grouped into three categories:

1. Likelihood that a site has released or has the potential to release hazardous substances into the environment;
2. Characteristics of the waste (e.g., toxicity and waste quantity); and
3. People or sensitive environments (targets) affected by the release.

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[17] Brender, J. D., Maantay, J. A., & Chakraborty, J. (2011). Residential proximity to environmental hazards and adverse health outcomes. American journal of public health, 101 Suppl 1(Suppl 1), S37–S52. doi:10.2105/AJPH.2011.300183

[18] Status of Superfund Sites in Areas Affected by Harvey. (2017, September 02). Retrieved from https://www.epa.gov/newsreleases/status-Superfund-sites-areas-affected-harvey

[19] Superfund Climate Resilience. (2019, February 25). Retrieved from https://www.epa.gov/Superfund/Superfund-climate-resilience

[20] https://www.harris.senate.gov/imo/media/doc/GAO_Superfund_CC_Letter_Final.pdf

[21] Hernández, A. R., & Dennis, B. (2017, October 16). Desperate Puerto Ricans line up for water - at a hazardous-waste site. Retrieved from https://www.washingtonpost.com/news/energy-environment/wp/2017/10/16/desperate-puerto-ricans-line-up-for-water-at-a-hazardous-waste-site/?noredirect=on&utm_term=.d5efef3987ab

After scores are calculated for one or more pathways, they are combined using a root-mean-square equation to determine the overall site score. Sites with HRS scores of 28.5 or greater are eligible for placement on the NPL, thereby allowing access to federal remediation funds.

The presence of a hazard, even one that has released into the environment, does not necessarily constitute high risk to human and environmental health. It is not clear if HRS scores account for disaster conditions and how hazard pathways might change in dramatic events. Due to the unique variability of individual Superfund sites, adverse health concerns will vary, depending on hazardous substances present, exposure pathway, dose, and population characteristics.

Data Sources

The following table provides a description and information on the update cycle of the variables contained in the Superfund analysis.

Table 2: *List and description of data variables included in the Superfund analysis.*

Superfund Sites	Location and facility information on National Priority List (NPL) and non-NPL Superfund sites.	EPA SEMS (2017)	Annually

Methodology and Discussion

Location and site information can be downloaded from the EPA's Superfund Enterprise Management System (SEMS). The data contains both NPL and non-NPL sites, including those that have been removed for successful remediation. There is an API available; however, count and location of sites returned using an API call varied and did not match the results of a direct data download. Therefore, the API is not currently active in this version of the model. Instead site location information is stored in a geodatabase and manually called into the model.

Superfund sites are filtered by their NPL status (NPL or non-NPL). A determination was made to include both NPL and non-NPL sites for this analysis because the classification is primarily used to guide further site investigations and prioritize remediation and cleanup by the EPA. For both lists, site density is calculated as the number of sites per ZCTA and then assigned a percentile rank. Since proximity to a hazard is important to understand potential exposure to a fugitive chemical or contaminant during a disaster, proximity interpolation was used to calculate the average distance from any point within a ZCTA to the nearest NPL or non-NPL site. Proximity interpolation was calculated using the Euclidean distance tool within Esri's ArcMap Spatial Analyst toolbox. The mean distance per ZCTA was assigned a percentile rank where ZCTAs that had smaller mean distances were ranked higher. A new percentile rank was assigned to each ZCTA from the sum of the density and proximity ranks.

Unfortunately, it is difficult to link Superfund site information with data on the site-specific contaminants present and, therefore, was excluded from this analysis. Common Superfund contaminants include lead, asbestos, dioxin, and radiation. Additional information about each Superfund site can be accessed independently through SEMS.

Results

There are 66 Superfund sites in Los Angeles, but only three sites are listed on the NPL. The non-NPL sites are scattered across the city in commercial and industrial corridors with a high concentration located east of Interstate 110 and south of the Santa Monica Freeway. There is one NPL site in the north, one along Interstate 5, and one along Interstate 110 south of Interstate 405. NPL and non-NPL sites are considered equal in the final percentile rank calculation. ZCTAs in the northeast section of the city along highway 170 and interstate 5, southeast of downtown, and adjacent to the Los Angeles Harbor have well above or above average vulnerability to Superfund hazards (see **Figure 3**).

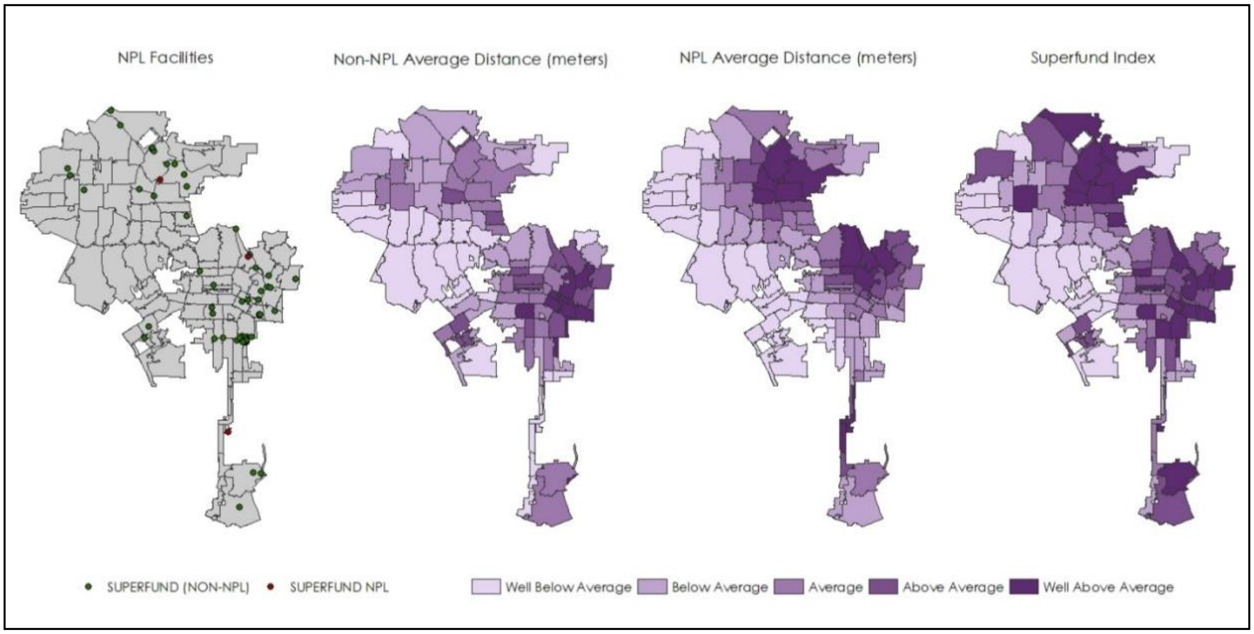

Figure 3 (left to right): *Distribution of Superfund sites (NPL and non-NPL), the average distance (meters) from an NPL and non-NPL site per ZIP code tabulation area, and total Superfund index for the City of Los Angeles.*

In the District of Columbia there are 29 Superfund sites and the Washington Navy Yard is the only site listed on the NPL. The majority of sites are located in the northeast quadrant of the city. ZCTAs in the northeast, southeast, and southwest have well above average vulnerability to Superfund hazards (see **Figure 4**).

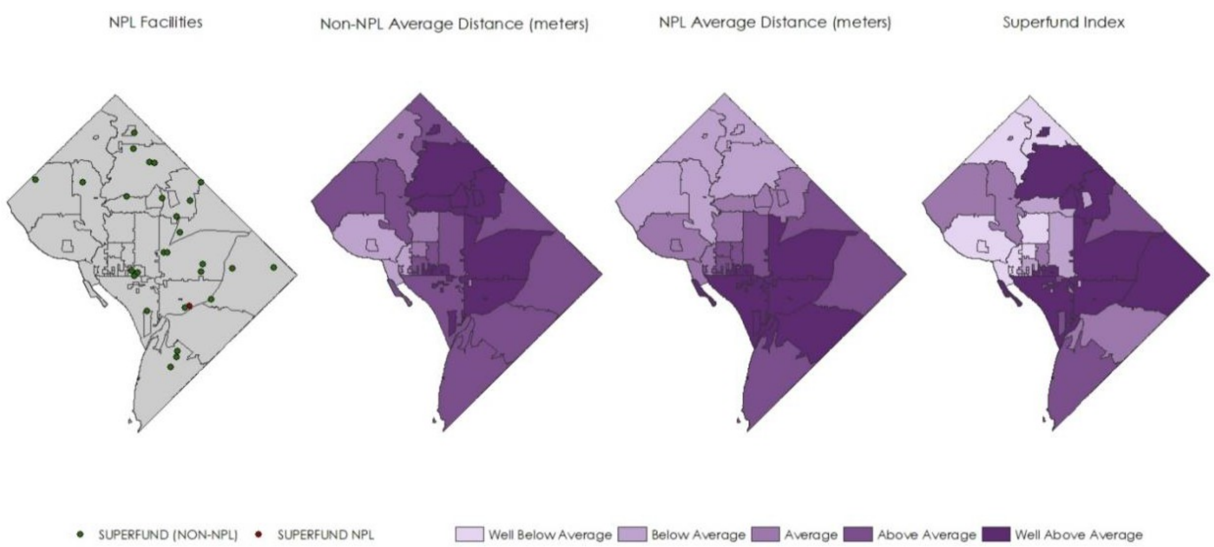

Figure 4 (left to right): *Distribution of Superfund sites (NPL and non-NPL), the average distance (meters) from an NPL and non-NPL site per ZIP code tabulation area, and total Superfund index for the District of Columbia.*

Toxic Release Inventory Facilities

The EPA's Toxics Release Inventory (TRI) is a database that contains information on specific toxic chemical releases, transfers, waste management, and pollution prevention activities from manufacturing facilities throughout the United States. Industrial facilities with 10 or more full-time employees that manufacture or process more than 25,000 pounds of a TRI chemical or otherwise use more than 10,000 pounds of a listed chemical in a calendar year are required to register under the Emergency Planning & Community Right-to-Know Act (EPCRA). For example, more than 100 Hurricane Harvey related toxic releases – on land, water, and air – were cataloged in the Houston area alone.[22] Most notably, 460,000 gallons of gasoline spilled from the Magellan Midstream Partners facility,[23] and toxic smoke from an explosion from the Arkema North America facility risked serious harm to residents and emergency responders.[24]

There are four major provisions under EPCRA:

1. Emergency Planning (§301-303)
2. Emergency Release Notification (§304)
3. Hazardous Chemical Storage Reporting Requirements (§311-312)

[22] Bajak, F., & Olsen, L. (2018, May 17). Silent Spills: In Houston and beyond, Harvey's spills leave a toxic legacy. Retrieved from https://www.houstonchronicle.com/news/houston-texas/houston/article/In-Houston-and-beyond-Harvey-s-spills-leave-a-12771237.php
[23] The Largest Harvey-Related Gasoline Spill Went Unknown for Weeks. (2017, September 25). Retrieved from https://www.texasmonthly.com/energy/the-largest-harvey-related-oil-spill-went-unknown-for-weeks/
[24] Mele, C. (2018, August 03). Chemical Maker and Its Chief Indicted for Explosions During Hurricane Harvey. Retrieved from https://www.nytimes.com/2018/08/03/business/arkema-chemical-plant-explosion-texas.html

4. Toxic Release Inventory (§313)

Section 304 requires immediate notification to the local emergency planning commission of the release of 355 "extremely hazardous substances" as well as another 700 "hazardous substances." The Occupational Safety and Health Administration (OSHA) requires facilities to prepare a material safety data sheet (MSDS) for all hazardous chemicals stored or used in a work place. There are over 500,000 products which require MSDS and Section 311 of EPCRA requires facilities with MSDSs for chemicals held above specified quantities to submit their MSDSs, or a list of chemicals, to the local emergency planning commission. If a facility chooses to submit a list of chemicals, they are required to identify the applicable physical or health hazard categories.

Facilities covered under Section 311 must submit annual inventories to local emergency planning commissions and fire departments as either a Tier I or Tier II report. Most states require Tier II reports which require more specific information about each individual chemical stored at a facility, including the average daily amount. This information can only be obtained from the local emergency planning commissions and is not available in a federal dataset.

Section 313 is the TRI program that tracks the management of toxic chemicals. Specifically, TRI includes information about:

- On-site releases to air, surface water and land
- On-site recycling, treatment and energy recovery associated with TRI chemicals
- Off-site transfers of chemicals from TRI facilities to other locations
- Pollution prevention activities at TRI facilities
- Releases of lead, mercury, dioxin and other persistent, bioaccumulative and toxic (PBT) chemicals
- Facilities in a variety of industry sectors and federal facilities

Due to the unique variability of individual toxic release inventory facilities, adverse health concerns will vary, depending on hazardous substances present, exposure pathway, dose, and population characteristics.

Data Sources

The following table provides a description and information on the update cycle of the variables contained in the toxic release inventory analysis.

Table 3: *List and description of data variables included in the toxic release inventory analysis.*

Toxic Release Inventory Facilities	Location and facility information on registered toxic release inventory facilities. Only includes facilities required to report to the EPA.	EPA EnviroFacts (2017)	Annually

Methodology and Discussion

There are multiple avenues to access facilities registered in the Toxic Release Inventory through data portals hosted by EPA. Basic site information including facility ID, facility name, ownership, and location can be accessed through the TRI EZ Search portal which retrieves data from the TRI database in EnviroFacts. EnviroFacts has a RESTful data service API, however, the facility information returned from the API is inconsistent with data downloaded through the TRI EZ Search portal. Therefore, the API is not currently active in this version of the model. Instead site location information is stored in a geodatabase and manually called into the model.

Only facilities which manufacture or dispose of regulated substances exceeding regulatory thresholds are required to submit annual reports to the EPA on the type and amount of substance released. Each facility is also required to report information to local emergency planning boards, but these reports are not monitored or tracked by EPA and are not available as a national dataset. Information about annual chemical releases for each facility is accessible through the TRI EZ Search. Due to unique chemical-specific reporting requirements, thresholds, and gaps in the reporting program, not all facilities will file a Form R in any one year. For example, there are over 1,600 toxic release inventory facilities in Los Angeles County but only 313 filed Form R reports in 2017.

The variability in annual reporting presents several challenges for this project. First, relying on annual reporting will underestimate the hazard at each facility and second, facilities are only required to report annual totals. Therefore, while these reports are useful for understanding the potential for a reported substance to be present at any given time, it is not confirmation the substance will be present at the time of a disaster. Access to historic Form R reports for each facility could shed light on the spectrum of substances used in the most recent five or 10-year period but requires advanced data processing and manipulation to summarize the information for each facility, which is beyond the scope of this project.

EPA's Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) version 2.1 is an impact assessment tool to measure the toxicity of chemical substances on the environment and human health. The tool standardizes toxicity using unit equivalents on ozone depletion, global warming potential, human health criteria, smog formation and eutrophication.[25] A potency value is provided for each chemical listed in TRACI. Because the potency value is standardized, direct comparison of discrete chemicals is possible. Chemicals are

[25] EPA. (2012). Tool for the reduction and assessment of chemical and other environmental impacts (TRACI) TRACI version 2.1 user's guide. EPA Office of Research and Development. EPA/600/R-12/554.

identified in TRACI using their unique CAS (Chemical Abstract Services) number, an internationally recognized standard for cataloging all known chemical substances.

The CAS number is an attribute in the Form R reports available through the TRI EZ Search database. For each chemical or substance reported, the CAS number is provided. Using a relational database structure, each facility can be linked to its Form R report and each chemical listed to the potency value available in TRACI. This is one example where linking disparate datasets within the ArcGIS environment allows analysts to view chemical potency across facilities and geography and could be used to evaluate the severity of the hazard. However, given the data and reporting constraints discussed above, the TRACI potency values were excluded from this version of the model. With more time and resources to evaluate the completeness of the Form R annual reports over an extended time period, TRACI potency values could be incorporated into the model.

Facility density and proximity are the two factors in this version of the model. Facility density was calculated as the number of facilities per ZCTA and then assigned a percentile rank. Proximity was calculated using the Euclidean distance tool in the spatial analyst toolbox in ArcGIS. The average distance to a TRI facility for each ZCTA was calculated and then assigned a percentile rank, where the lower mean value received a higher rank. A new percentile rank was assigned to each ZCTA from the sum of the density and proximity ranks.

Results

In total there are 409 TRI facilities in Los Angeles and 19 in the District of Columbia. The highest vulnerable ZCTAs to TRI facilities in Los Angeles are in the northeast around the North Hollywood and Sun Valley neighborhoods, adjacent to downtown, and in the south adjacent to Los Angeles Harbor. The highest vulnerable ZCTAs in the District of Columbia in the northeast and southeast quadrants of the city (see **Figure 5** and **Figure 6**).

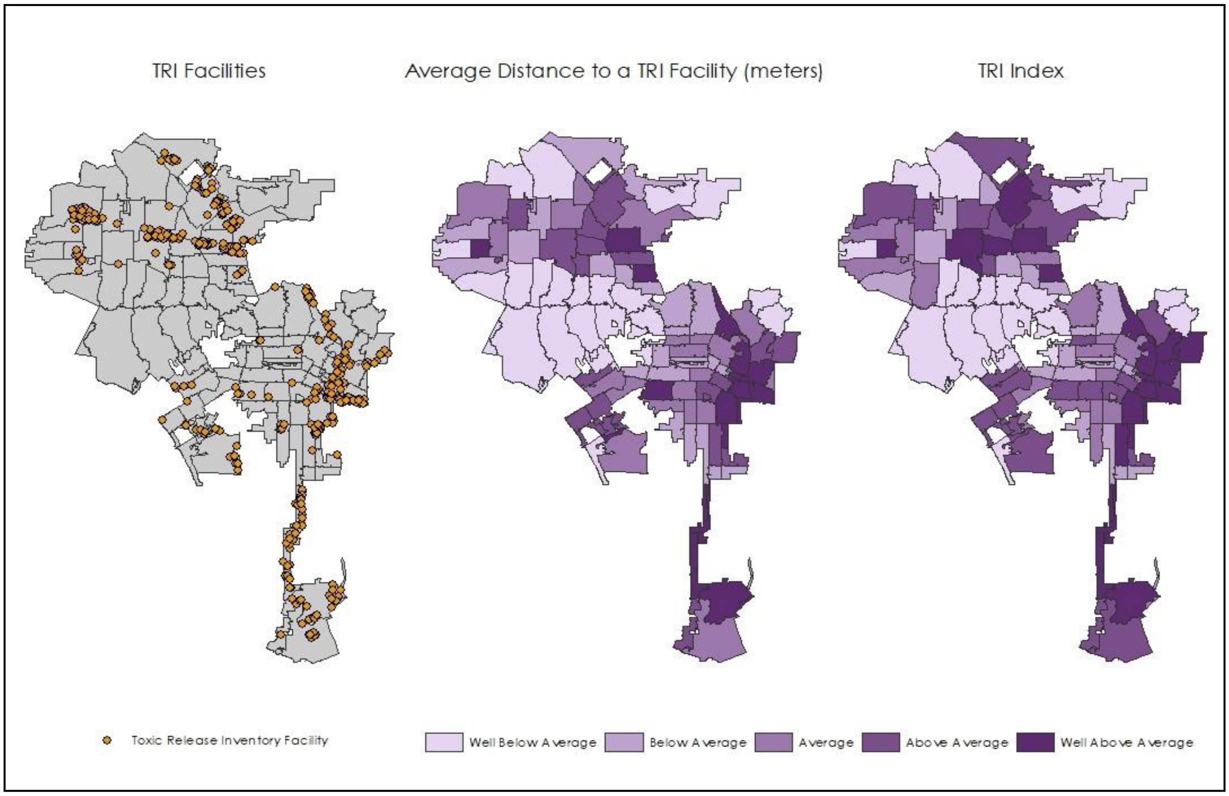

Figure 5 (left to right): *Distribution of toxic release inventory facilities, the average distance (meters) from a facility per ZIP code tabulation area, and total toxic release inventory index for Los Angeles.*

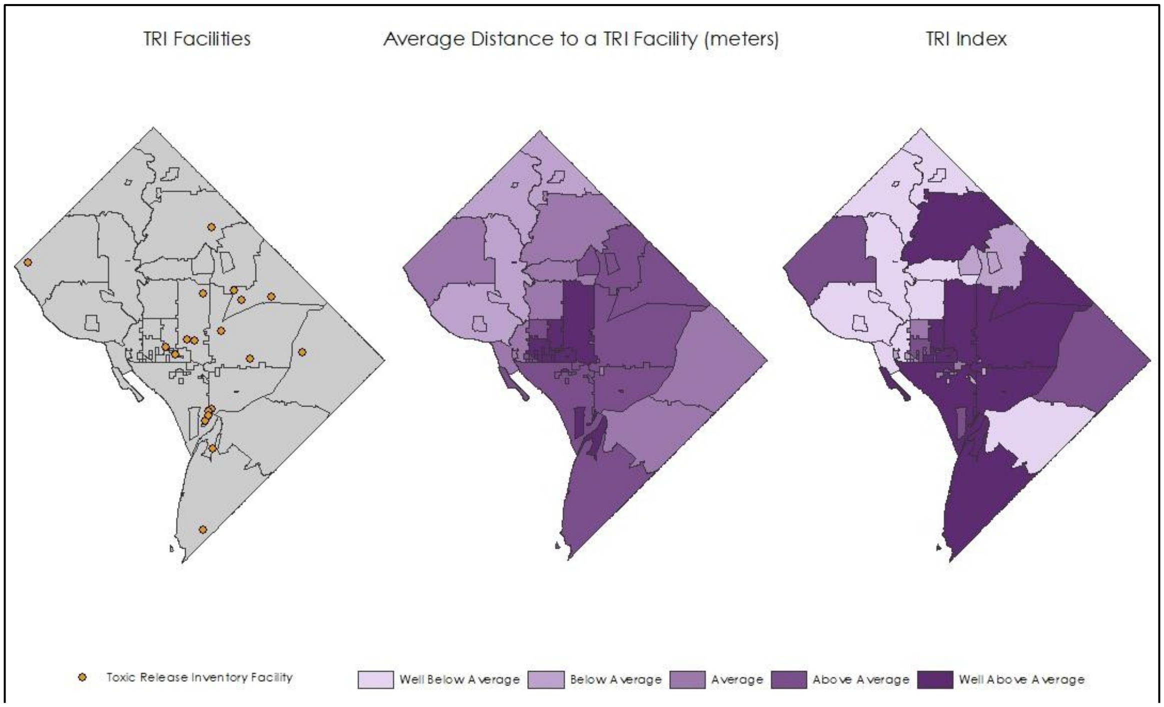

Figure 6 (left to right): *Distribution of toxic release inventory facilities, the average distance (meters) from a facility per ZIP code tabulation area, and total toxic release inventory index for the District of Columbia.*

SOLID WASTE AND DEBRIS

The quantity of solid waste and debris after disasters (especially hurricanes, wind, and seismic events) can be excessive. Debris and the possibility of contaminants, such as lead-based paint in older construction, asbestos, and other hazardous materials, may be present and present long-term hazards.[26] When plastics, asbestos material, treated wood (outdoor decking, utility poles, support beams, piping) and other building materials, and disaster debris find their way into burn pits and brush fires, they can produce emissions, including toxic volatile organic compounds and heavy metals.[27]

For many years, the most common preservative mixture used for treated wood was CCA, a combination of chromium, copper, and arsenic. When wood treated with this preservative is burned, some of the arsenic is released into the air with the fly ash, and the rest is concentrated in the ash that remains. Prior to 2004, wood treated with chromated arsenicals was used in residential structures such as decks and playsets. In December 2003, manufacturers voluntarily discontinued manufacturing chromated arsenicals-treated wood products for homeowner use. However, the EPA has not banned chromated arsenicals and does not require the removal of existing structures made with wood treated with chromated arsenicals or the surrounding soil.

Mercury can become airborne through burning of coal, oil and wood, and mercury-containing wastes (such as consumer products that contain mercury, like electronic devices, batteries, light bulbs and thermometers). This airborne mercury can fall to the ground in raindrops, in dust, or simply due to gravity (known as "air deposition"). Specific adverse health concerns vary depending on the type of debris, exposure pathway, and dose.

Exposure to smoke from burning materials and runoff from temporary storage of debris can also present long-term issues. Burning debris can be particularly dangerous for people with asthma or respiratory diseases.

Data Sources

The following table provides a description and information on the update cycle of the variables contained in the estimated building debris analysis.

[26] Skinner, J. (2011). *Managing Wastes Produced by Natural Disasters* (Issue brief). Solid Waste Association of North America.
[27] EPA Hurricane Maria Update, Friday January 5, 2018. (2018, January 05). Retrieved from https://www.epa.gov/newsreleases/epa-hurricane-maria-update-friday-january-5-2018

Table 4: *List and description of data variables included in the estimated building debris analysis.*

Historic Data on DC Buildings	High resolution dataset of building polygons in the District of Columbia. Includes historic data for each structure including year of construction, number of floors, building height, and construction materials.	District of Columbia (2017)	Unknown
Countywide Building Outlines	High resolution dataset of building polygons for Los Angeles County. Includes data on each structure including year of construction.	Los Angeles County (2014)	Unknown

Methodology and Discussion

The Federal Emergency Management Agency (FEMA) has a detailed debris estimation methodology for use during an emergency.[28] This methodology was used to estimate tons of debris per ZCTA in the District of Columbia and the City of Los Angeles based on building size and type.

FEMA has developed several sets of equations to calculate the amount of building debris based on use characteristics. Specifically, they have developed equations for general buildings, single family residence, and mobile homes. These equations are noted below.

Table 5*: Equations to calculate building debris. L is the length of the building, W is the width of the building, H is the height of the building, and VCM is a vegetation multiplier to account for trees and other natural debris that may accumulate in more residential areas.*

General	(L*W*H*0.33)/27	(F*H*0.33)/27
Single-family residence	L*W*S*0.20*VCM	F*S*0.20
Mobile Homes	(L * W * H)/27	(F*H)/27

In order to improve accuracy and account for buildings that are not perfectly square, the area of the building footprint was calculated (F) using the building polygon dataset available for the City of Los Angeles and District of Columbia. Due to lack of data availability, the vegetation multiplier value was excluded from the single-family residence calculations.

[28] Debris, Estimating, Field Guide, & FEMA. (2010). *Debris estimating field guide*. Retrieved from https://www.fema.gov/pdf/government/grant/pa/fema_329_debris_estimating.pdf.

Building footprint data was acquired for Los Angeles and District of Columbia from the County of Los Angeles and the DC Open Data Portal, respectively. Both datasets include building height and use information. These values were than aggregated to the ZCTA level to provide a worse-case estimate of total tons of debris for each ZCTA in the event of a natural disaster. The total estimated debris per ZCTA was then assigned a percentile rank.

Results

The result of this analysis presents a worst-case scenario in which all buildings and homes within a ZCTA have been destroyed. They can be useful in planning and recovery efforts, especially when viewed in conjunction with estimated prevalence of lead and asbestos (see **Figure 7**). Identifying areas with large amounts of debris where structures are also likely to contain lead and asbestos provides a measure of potential exposure to these hazardous materials. Furthermore, debris can not only be a hinderance to evacuation, search and rescue, and other recovery efforts, but accurate estimates of debris are necessary to determine whether a disaster declaration is approved.[29] While this tool should not replace official debris estimates, it can assist in rapid, informal assessments in combination with other hazards.

Debris estimates for the District of Columbia are evenly spread across the city with no clear spatial patterns. Higher density residential neighborhoods have higher debris estimates compared to commercial and office districts downtown. In Los Angeles the ZIP code tabulation areas with higher debris estimates are in the northwest and south.

[29] Debris, Estimating, Field Guide, & FEMA. (2010). *Debris estimating field guide*. Retrieved from https://www.fema.gov/pdf/government/grant/pa/fema_329_debris_estimating.pdf

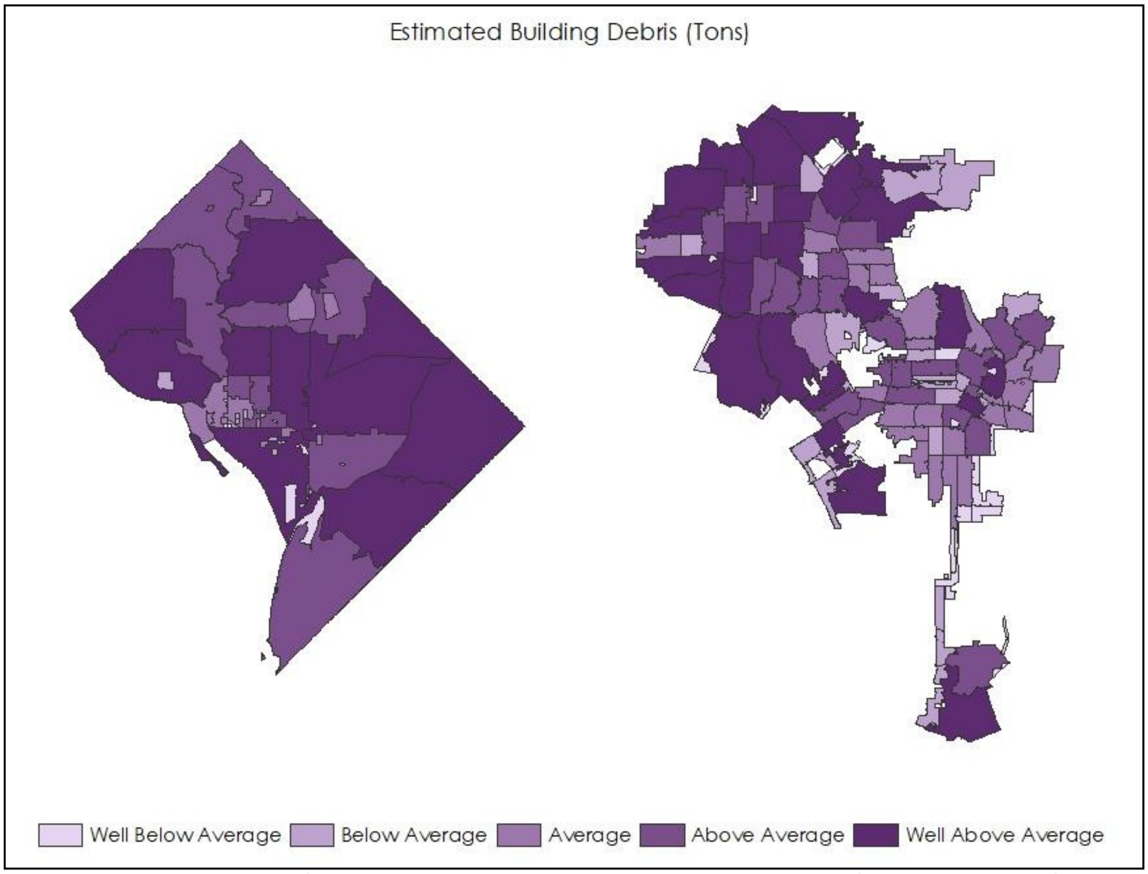

Figure 7: *Estimated tons of building debris per ZIP code tabulation area for the District of Columbia (left) and the City of Los Angeles (right).*

LEAD

Disasters, such as tornadoes, hurricanes, earthquakes or floods can result in significant damage to buildings. In the wake of Hurricane Katrina, more than 100,000 homes were destroyed or damaged and a significant amount of sediment was deposited throughout the city of New Orleans. Researchers identified the potential for increased lead hazards from environmental lead contamination of soils[30] originating from common renovation activities such as sanding, cutting, and demolition when performed in structures that contain lead-based paint producing lead-contaminated dust.[31] Lead is commonly found in construction materials used prior to 1978 when federal law banned the use of lead in building materials.[32] Lead-based paint hazards are harmful to adults and children.

[30] Rabito, F. A., Iqbal, S., Perry, S., Arroyave, W., & Rice, J. C. (2012). Environmental Lead after Hurricane Katrina: Implications for Future Populations. Environmental Health Perspectives, 120(2), 180-184. doi:10.1289/ehp.1103774

[31] Goldman, L., & Coussens, C. (2007). *Environmental public health impacts of disasters: Hurricane Katrina: Workshop summary*. Washington, D.C.: National Academies Press.

[32] USA, Housing and Urban Development, Hurricane Sandy Rebuilding Task Force - Indoor Environmental Pollutants Work Group. (2015). *Homeowners and renters guide to reducing lead hazards after disasters*.

Lead poisoning can happen if a person is exposed to very high levels of lead over a short period of time. When this happens, a person may feel abdominal pain, constipated, tired, headachy, Irritable, loss of appetite, memory loss, pain or tingling in the hands and/or feet, or weak. Exposure to high levels of lead may cause anemia, weakness, and kidney and brain damage, and very high lead exposure can cause death. Lead can cross the placental barrier, which means pregnant women who are exposed to lead also expose their unborn child. It can damage a developing baby's nervous system, and even low-level lead exposures in developing babies have been found to affect behavior and intelligence. Lead exposure can cause miscarriage, stillbirths, and infertility (in both men and women). Generally, lead affects children more than adults. Children tend to show signs of severe lead toxicity at lower levels than adults, and lead poisoning has occurred in children whose parents accidentally brought home lead dust on their clothing. [33]

Data Sources

The following table provides a description and information on the update cycle of the variables contained in the estimated lead analysis.

Table 6: *List and description of data variables included in the estimated lead analysis.*

Historic Data on DC Buildings	High resolution dataset of building polygons in the District of Columbia. Includes historic data for each structure including year of construction, number of floors, building height, and construction materials.	District of Columbia (2017)	Unknown
Countywide Building Outlines	High resolution dataset of building polygons for Los Angeles County.	Los Angeles County (2014)	Unknown
Countywide Assessor Parcel Data	Information and location of every land parcel in the county. Includes information such as assessed land value and building construction year.	Los Angeles County (2016)	Unknown

Methodology and Discussion

To calculate the percentage of buildings constructed prior to 1978, a building dataset must contain the attribute for year of construction. The countywide building outlines for Los Angeles County do not contain a field for construction year; however, the countywide assessor parcel data does. For the District of Columbia, the building data has a data field for construction year. A spatial join was performed to append the construction year from the Los Angeles County assessor parcel data to the building outlines layer.

[33] CDC - Lead: Health Problems Caused by Lead - NIOSH Workplace Safety and Health Topic. (n.d.). Retrieved from https://www.cdc.gov/niosh/topics/lead/health.html

Calculating the percentage of buildings constructed prior to 1978 allows decision-makers to understand the relative likelihood of the presence and concentration of lead dust in building debris. For example, a neighborhood or subdivision constructed after 1978 would not contain lead in building materials and therefore is less a concern for first responders, recovery personnel, or residents returning to sift through debris than an older neighborhood where the presence of lead is more likely. This calculation can also be combined with estimated debris calculations to understand a preliminary concentration of lead dust in debris after a disaster and may guide PPE requirements for clean-up personnel or public communications as residents return to the disaster area to sift through debris.

One limitation of these two datasets is the lack of information about whether a structure had lead-based paint or other lead-based construction materials removed as part of rehabilitation, a removal program, or other renovations. The percentage of buildings constructed prior to 1978 for each ZCTA is assigned a percentile rank for inclusion into the final disaster recovery environmental hazard index.

Results

Consistent with patterns of urban development, the percentage of structures constructed prior to 1978 in Los Angeles and the District of Columbia is quite high. Combining data from both cities, the average percentage of the building stock constructed prior to 1978 is eighty-six (86) percent. In the District of Columbia, the average is eighty-three (83) percent, and in Los Angeles the average is eighty-seven (87) percent. As previously discussed, efforts to mitigate and remove hazardous lead-based materials from structures have reduced the vulnerability; however, the results of this model suggest precautions should be taken to avoid exposure until field testing can validate the presence and concentration of lead in building debris. **Figure 8** shows the percentage of building stock constructed prior to 1978 for each ZIP code tabulation area.

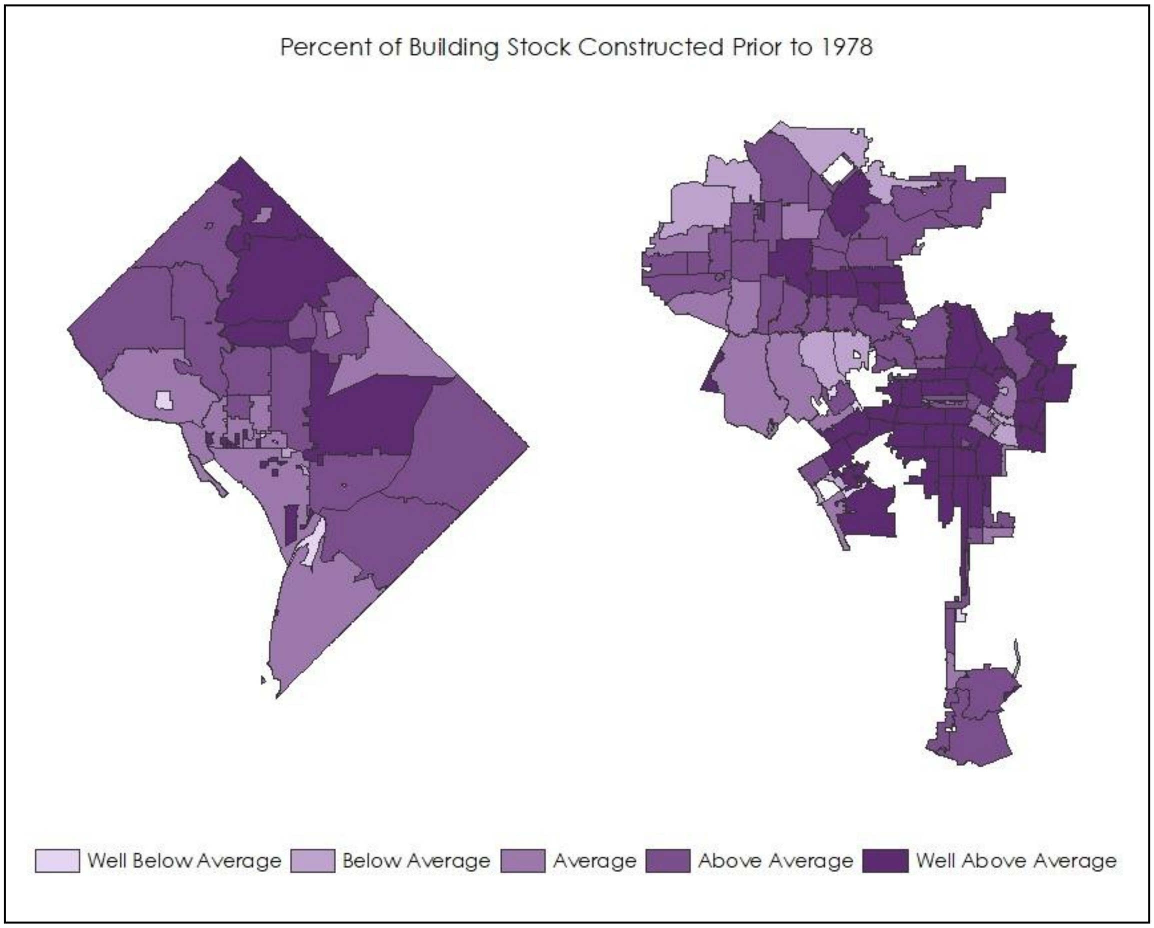

Figure 8 (left to right): *Percentage of buildings per ZIP code tabulation area constructed prior to 1978 for the District of Columbia and the City of Los Angeles. The data does not factor recent building renovations or whether lead-based paint has been removed as part of a clean-up program.*

ASBESTOS

Asbestos is a microscopic and carcinogenic fiber that was commonly used in building materials through the 1970s. These products include fireproof coatings, concrete and cement, bricks, pipes, gaskets, insulation, drywall, flooring, roofing, joint compound, paints, and sealants. Asbestos also exists in electrical appliances, plastics, rubber, mattresses, flowerpots, lawn furniture, hats, and gloves.[34] Disasters can damage asbestos-containing materials in ways that lead to asbestos exposure among residents, first responders, and clean-up crews. When materials containing asbestos are disturbed, toxic dust may be inhaled and become embedded in the lining of organs, where it can develop into mesothelioma cancer .[35] While it is now strictly regulated in the United States, the toxin can still be found in older buildings constructed prior to 1980, thus complicating the rebuilding process after a disaster.

[34] Fusco, K. (2017, March 03). Disasters Increase Asbestos Exposure Beyond Point of Impact. Retrieved from https://www.asbestos.com/blog/2015/02/03/asbestos-exposure-after-disaster/
[35] USA, Housing and Urban Development, Hurricane Sandy Rebuilding Task Force - Indoor Environmental Pollutants Work Group. (2015). *Homeowners and renters guide to asbestos cleanup after disasters.*

- In Malibu, California, a coastal community hit hard by fires in 1993, 268 houses were destroyed. Most burned to their foundations. The city gave property owners six weeks to remove debris and then began removing remaining household debris. Later, the California State License Board widely acknowledged that homes constructed between 1930 and 1950 may have contained asbestos in 16 areas.[36]
- Two months after the catastrophic EF5 tornado plowed through Joplin, Missouri in 2011, the EPA issued a statement warning Joplin residents and anyone else involved in the clean-up efforts and demolition of damaged buildings to wear protective gear, including gloves and respirators to avoid the risk of developing mesothelioma and other asbestos-related diseases.[37]
- In December 2014, a large cloud of smoke and asbestos engulfed Roermond, Netherlands, after boat sheds at a marina caught fire. Dutch officials declared it an emergency, because asbestos dust from the burning boats covered most of the city's homes, cars, streets. and roofs.[38]

Data Sources

The following table provides a description and information on the update cycle of the variables contained in the estimated asbestos analysis.

Table 7: *List and description of data variables included in the estimated asbestos analysis.*

Historic Data on DC Buildings	High resolution dataset of building polygons in the District of Columbia. Includes historic data for each structure including year of construction, number of floors, building height, and construction materials.	District of Columbia (2017)	Unknown
Countywide Building Outlines	High resolution dataset of building polygons for Los Angeles County.	Los Angeles County (2014)	Unknown
Countywide Assessor Parcel Data	Information and location of every land parcel in the county. Includes information such as assessed land value and building construction year.	Los Angeles County (2016)	Unknown

Methodology and Discussion

To calculate the percentage of buildings constructed prior to 1980, a building dataset must contain the attribute for year of construction. The countywide building outlines for Los Angeles County do not contain a field for construction year; however, the countywide assessor parcel

[36] Ibid.
[37] Ibid.
[38] Ibid.

data does. For the District of Columbia, the building data has a data field for construction year. A spatial join was performed to append the construction year from the Los Angeles County assessor parcel data to the building outlines layer.

Calculating the percentage of buildings constructed prior to 1980 allows decision-makers to understand the relative likelihood of the presence and concentration of asbestos dust in building debris. For example, a neighborhood or subdivision constructed after 1980 would not contain asbestos in building materials and therefore is less a concern for first responders, recovery personnel or residents returning to sift through debris than an older neighborhood where the presence of asbestos in building debris is more likely. This information can also be combined with estimated debris calculations to understand a preliminary concentration of asbestos dust in debris after a disaster and may guide PPE requirements for clean-up personnel or public communications as residents return to the disaster area to sift through debris.

One limitation of these two datasets in particular, is the lack of information about whether a structure had asbestos removed as part of rehabilitation, a removal program, or other renovations. The percentage of buildings constructed prior to 1980 for each ZCTA is assigned a percentile rank for inclusion into the final disaster recovery environmental hazard index.

Results

Consistent with patterns of urban development, the percentage of structures constructed prior to 1980 in Los Angeles and the District of Columbia is quite high. Combining data from both cities, the average percentage of building stock constructed prior to 1980 is eighty-six (86) percent. In the District of Columbia, the average is eighty-four (84) percent, and in Los Angeles the average is eighty-seven (87) percent. As previously discussed, efforts to mitigate and remove asbestos from structures has reduced the vulnerability; however, the results of this model suggest precautions should be taken to avoid exposure until field testing can validate the presence and concentration of asbestos in building debris. **Figure 9** shows the percentage of the building stock constructed prior to 1980 for each ZIP code tabulation area.

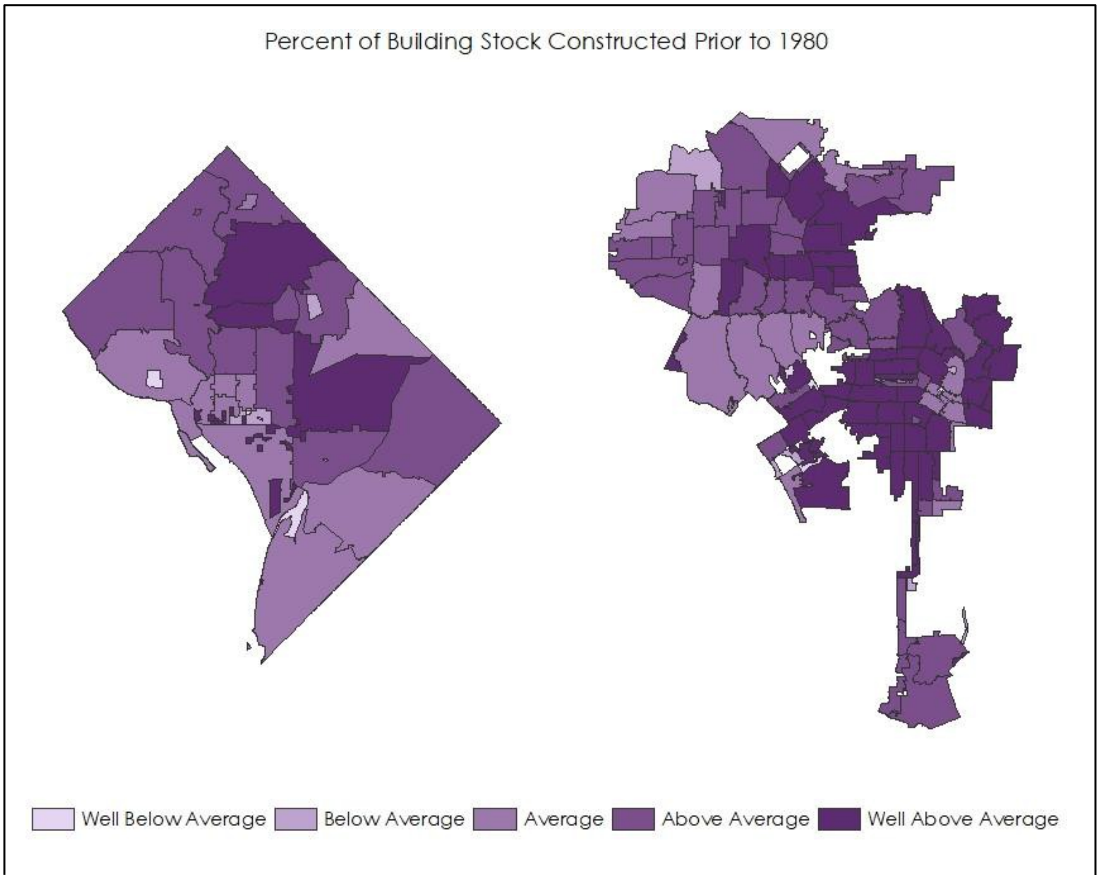

Figure 9 (left to right): *Percentage of buildings per ZIP code tabulation area constructed prior to 1980 for the District of Columbia and the City of Los Angeles. The data does not factor recent building renovations or whether asbestos has been removed as part of a clean-up program.*

COMPOSITE ESTIMATED DEBRIS INDEX

The estimated debris and lead and asbestos calculations were combined into a single estimated debris index, because lead and asbestos exposure is largely dependent on the amount and location of debris. The sum of each percentile rank was recalculated to provide a new estimated debris index percentile rank. **Figure 10** and **Figure 11** provide a side-by-side comparison of each indicator and the composite index. The ZIP codes most vulnerable are locations with greater concentrations of older buildings. While building age is not a factor in the FEMA debris estimate calculations used in this model, older structures are more vulnerable due to less robust building standards which includes the widespread use of construction materials containing lead and asbestos.

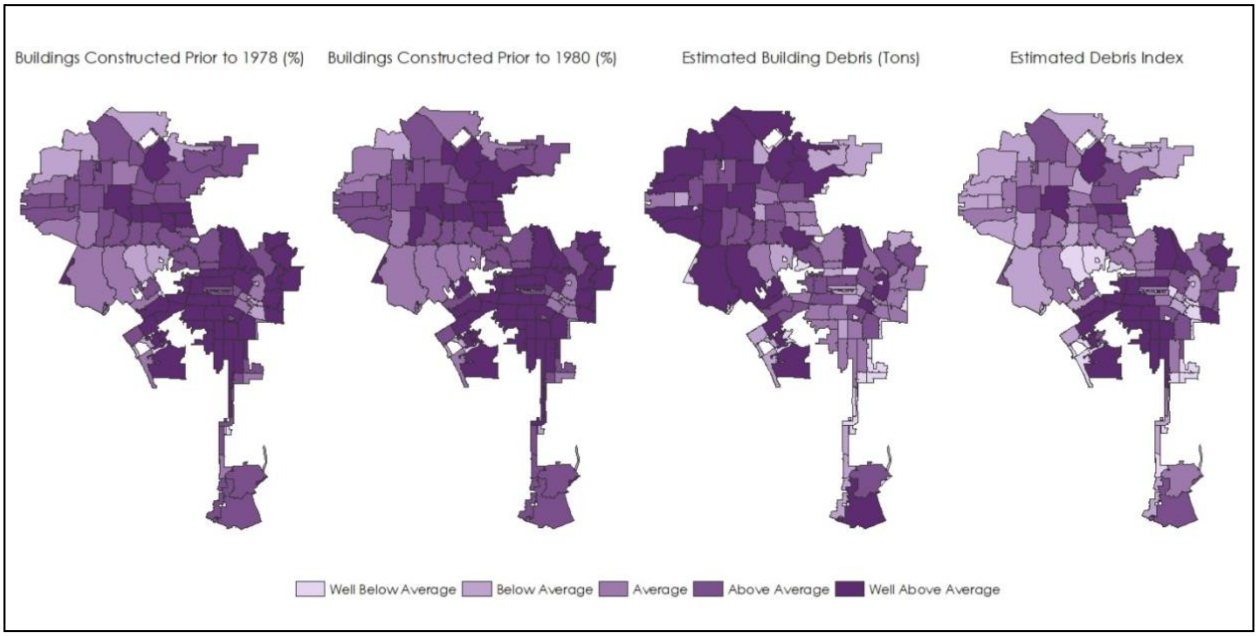

Figure 10: *The estimated building debris index for the City of Los Angeles incorporates the percentile ranks from the lead, asbestos, and estimated building debris indicators.*

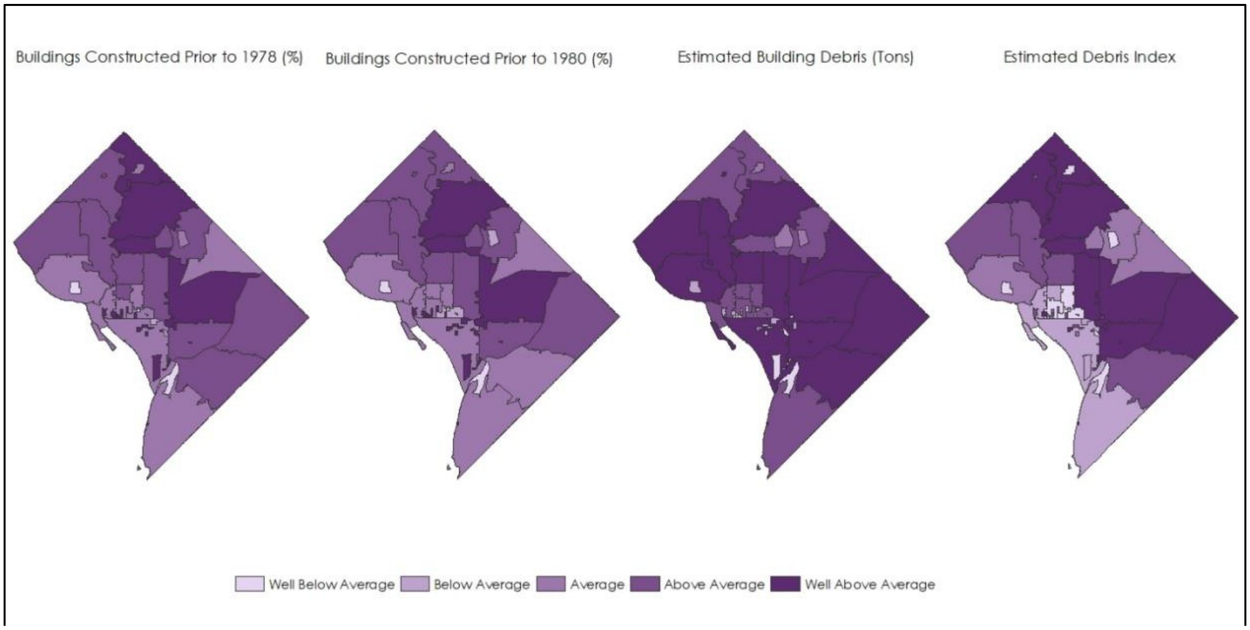

Figure 11: *The estimated building debris index for the District of Columbia incorporates the percentile ranks from the lead, asbestos, and estimated building debris indicators.*

Constructing the Disaster Recovery Environmental Health Index

To fulfill the pilot objective, each of the aforementioned environmental health and built environment datasets was combined with the social environmental index to produce a composite disaster recovery environmental health index. The final index was calculated using a percentile rank of the sum of each indicator. Because the model is not predicting chemical releases or other fugitive environmental hazards or a particular public health outcome occurring during a catastrophic event, the results can only be interpreted as a value of relative vulnerability. The percentile rank values are translated to a scale of "well below average" to "well above average" (see **Figure 12**). The higher the raw value, the greater the vulnerability to environmental hazards. A lower value, or lower vulnerability, does not necessarily indicate a lack of vulnerability to environmental hazards during or after a disaster. Conversely, a higher value does not assure exposure to an environmental hazard will occur. Instead, the results serve as a screening tool to guide analysts, environmental health professionals, emergency managers, and decision-makers in determining appropriate actions to avoid adverse public health outcomes.

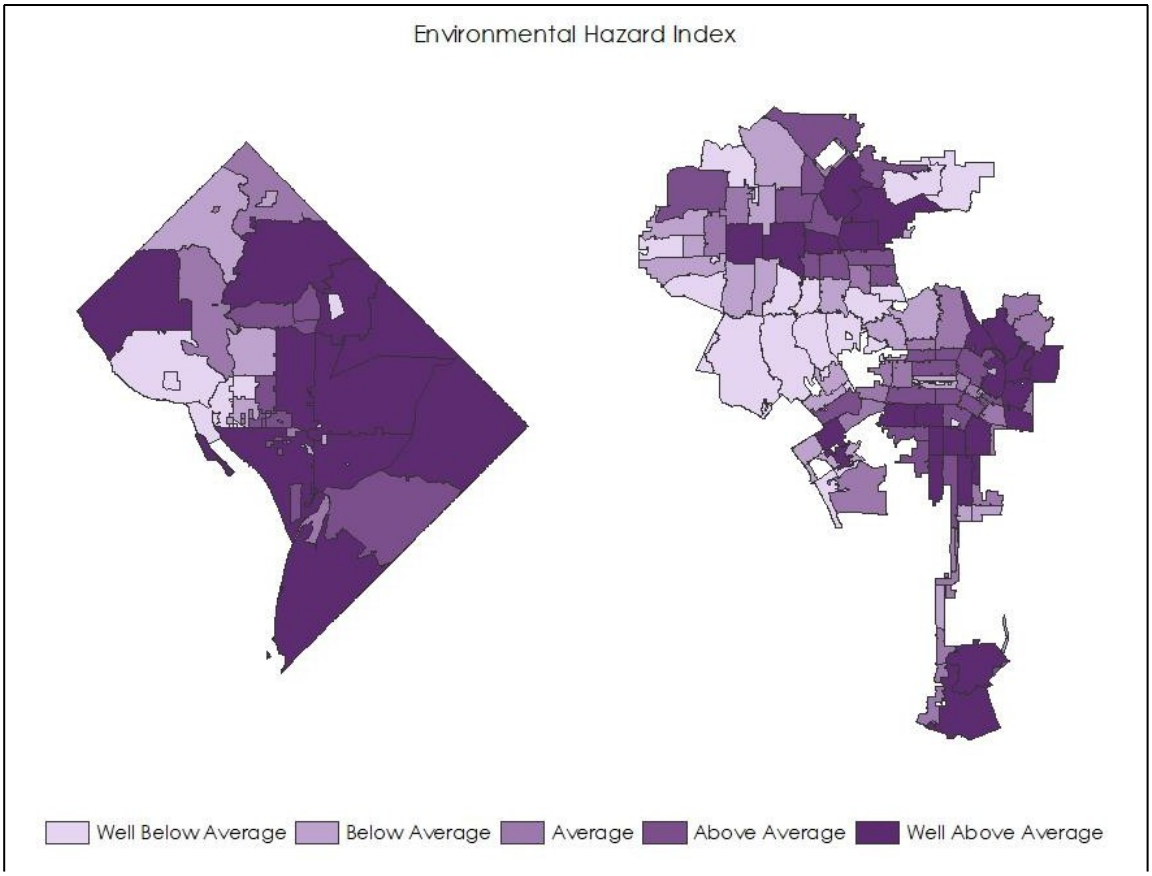

Figure 12 (left to right): *The disaster recovery environmental hazard index mapped at the ZIP code tabulation area for the District of Columbia and City of Los Angeles. Higher values indicate a greater vulnerability relative to each city and are interpreted as a well below average to well above average scale.*

The results of the composite index demonstrate a loose spatial correlation with the original social vulnerability index calculated by the CDC and this project's social environmental index. Where many ZIP code tabulation areas experience higher social environmental indices, vulnerability to known environmental hazards is also present. However, it appears the presence, density, and proximity to environmental hazards does influence overall vulnerability rankings. For example, the presence of a non-NPL superfund sites in neighborhoods of Northwest District of Columbia increases the vulnerability in these ZIP code tabulation areas to "well above average." Conversely, the absence of environmental hazards can lower the vulnerability of a ZIP code tabulation area even when the social environmental index is above average. In neighborhoods southwest of downtown Los Angeles where the social environmental index is well above average, lower environmental hazard rankings reduces the overall vulnerability from well above average to above average.

Comparing the disaster recovery environmental index results side-by-side with individual indicators illustrates the subtlety of changes in vulnerability. This observation demonstrates the usefulness of evaluating vulnerability in a more comprehensive way, especially when combining social vulnerability with environmental hazards rather than viewing each indicator separately. When studying two ZIP codes in northwest Los Angeles, identified by the red box in **Figure 13**, the northern ZIP within the red box appears to rank above average or well above average in three of the four themes. In the southern ZIP code in this example, the results are less clear. While social vulnerability is well above average, the environmental hazards are average or below average across the other themes.

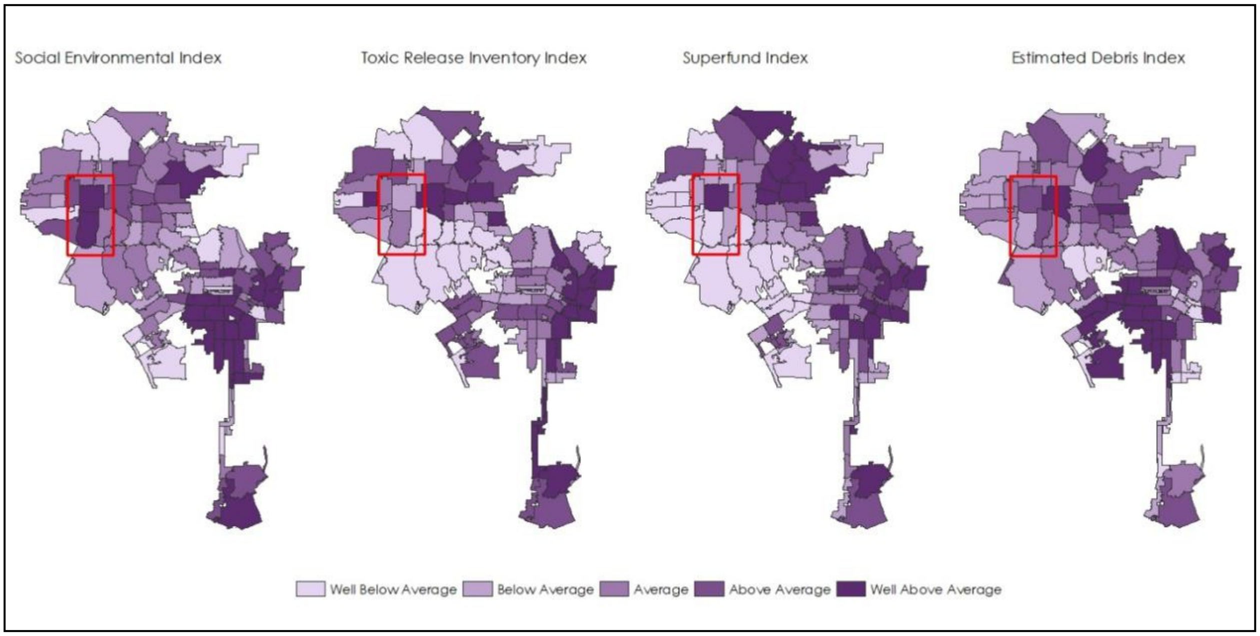

***Figure 13**: Comparing two ZIP code tabulation areas in northwest Los Angeles (shown in the red box) for the social environmental index, toxic release inventory index, superfund index and estimated debris index. Viewing the indicators side-by-side demonstrates the subtle changes in vulnerability across each indicator that requires a more comprehensive approach to more accurately determine vulnerability.*

In the composite index (see **Figure 14**), it becomes clearer how each variable contributes to overall vulnerability. The northern ZIP code is well above average as expected but the southern ZIP code is identified as average despite the high social vulnerability factor. The absence of environmental hazards relative to other areas of Los Angeles in the southern ZIP code factor into the composite index.

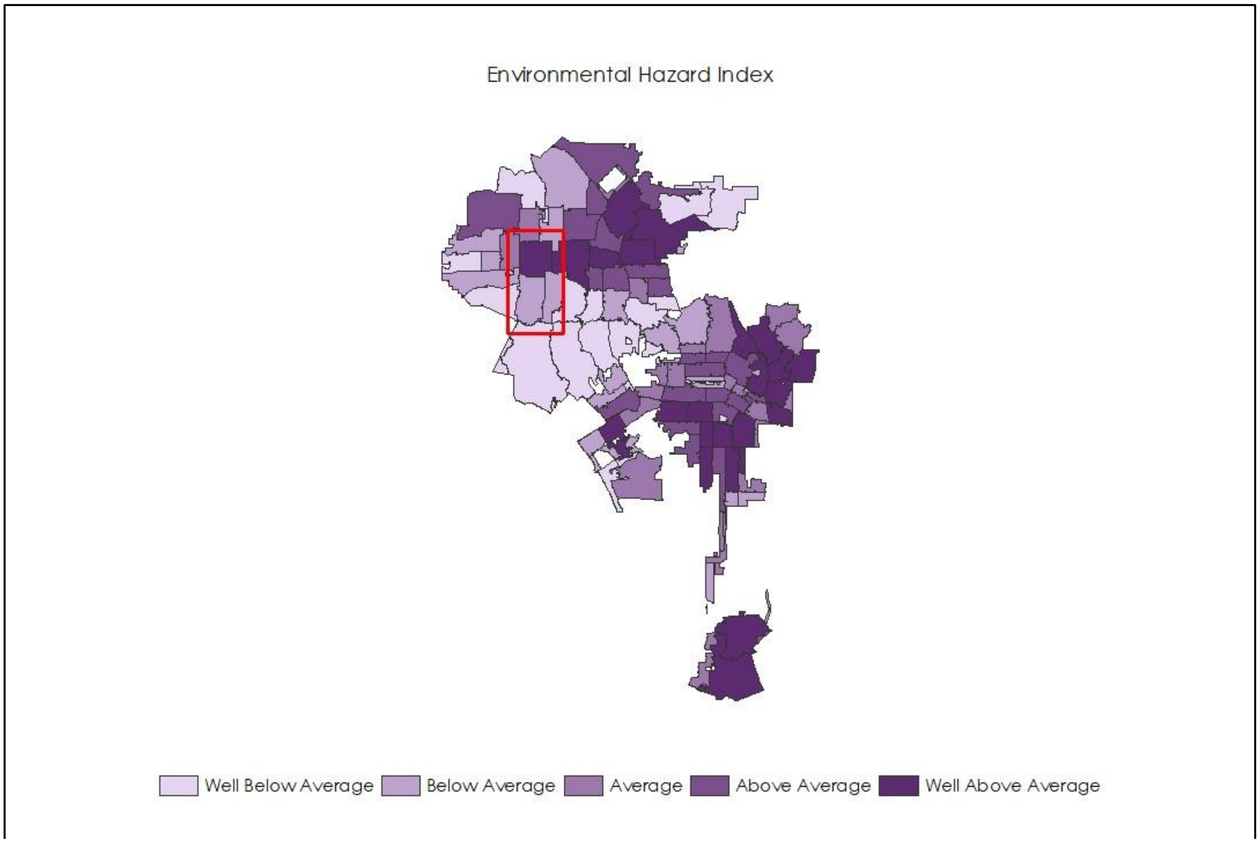

***Figure 14**: The composite disaster recovery environmental hazard index for the two ZIP code tabulation areas described in the previous figure. The northern ZIP code is classified as well above average vulnerability and the southern ZIP code is below average due to the lack of environmental hazards despite having well above average social environmental index*

Results

Google satellite imagery and street view imagery was used to broadly validate the results and to also demonstrate the applicability of the index in an actual public health emergency. Viewing the world through a series of interactive, two-dimensional choropleth web maps is not the natural way we perceive our environment. Translating the results of this analysis using satellite imagery and street view provides another perspective and is useful to illustrate the nuances in vulnerability across our built environment. **Figure 15** shows a well above average ZIP code adjacent to the Port of Los Angeles. This ZIP code contains a busy industrial port and adjacent residential neighborhoods (see **Figure 16** and **Figure 17**).

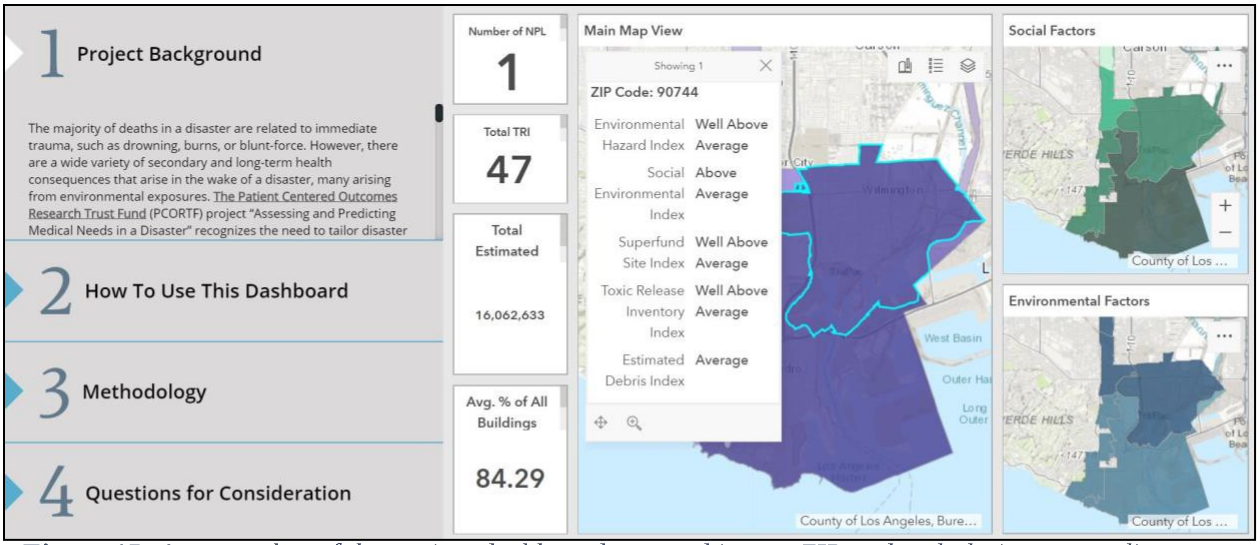

***Figure 15**: A screenshot of the project dashboard, zoomed in to a ZIP code tabulation area adjacent to the Port of Los Angeles. The ZIP code tabulation area contains a major industrial port facility and residential neighborhoods. The area is ranked well above average in the disaster recovery environmental hazard index.*

***Figure 16**: A Google Maps satellite image of the ZIP code tabulation area shown in Figure 15. The Port of Los Angeles and adjacent neighborhoods are visible.*

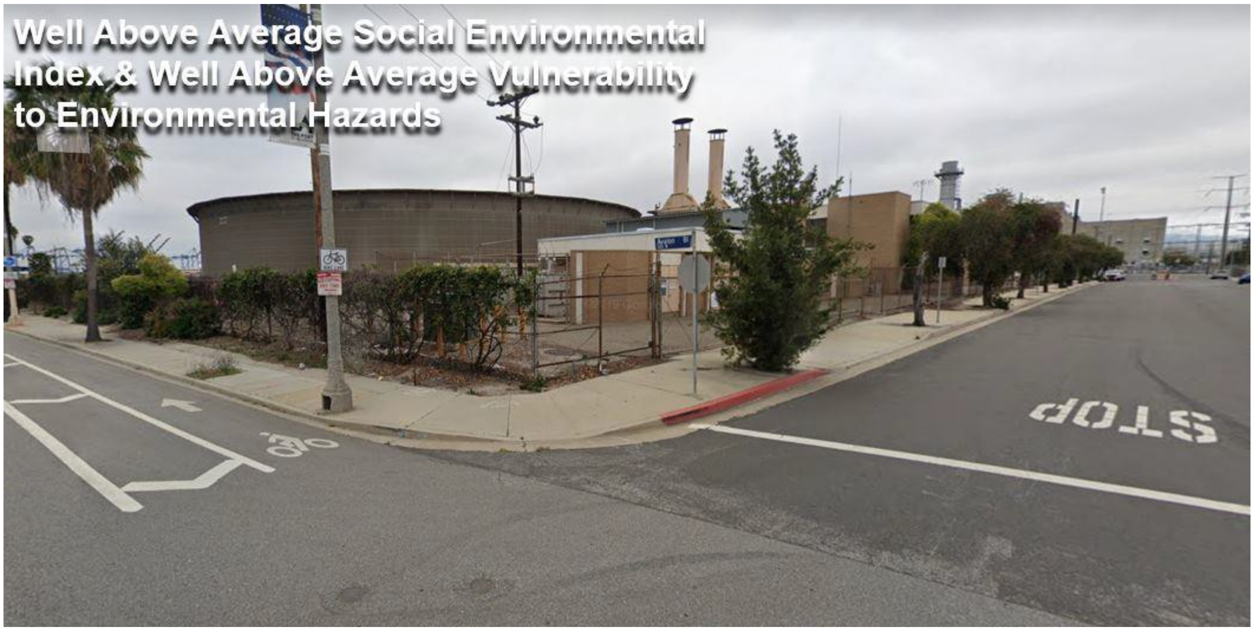

***Figure 17**: A Google Maps Street View image of the ZIP code tabulation area shown in **Figure 15**. An above ground storage tank and other industrial facilities are visible.*

In other neighborhoods of Los Angeles, vulnerability is less obvious but highlights an important distinction that has been discussed throughout this report. A community or neighborhood can score well above average with the right combination of indicators without the presence of a major industrial complex. In fact, based on this analysis, it is possible a densely populated neighborhood of older building stock with a relatively vulnerable population can be equally vulnerable to an area adjacent to a manufacturing facility. Moreover, areas of light manufacturing located in suburban commercial districts can be equally hazardous. **Figure 18** and **Figure 19** illustrate the nuances in vulnerability well. Both figures show a typical suburban development pattern captured from satellite imagery and Google Maps Street View. One neighborhood ranks well above average in the social environmental index and above average in environmental hazards while the other neighborhood ranks average in the social environmental index and below average in environmental hazards.

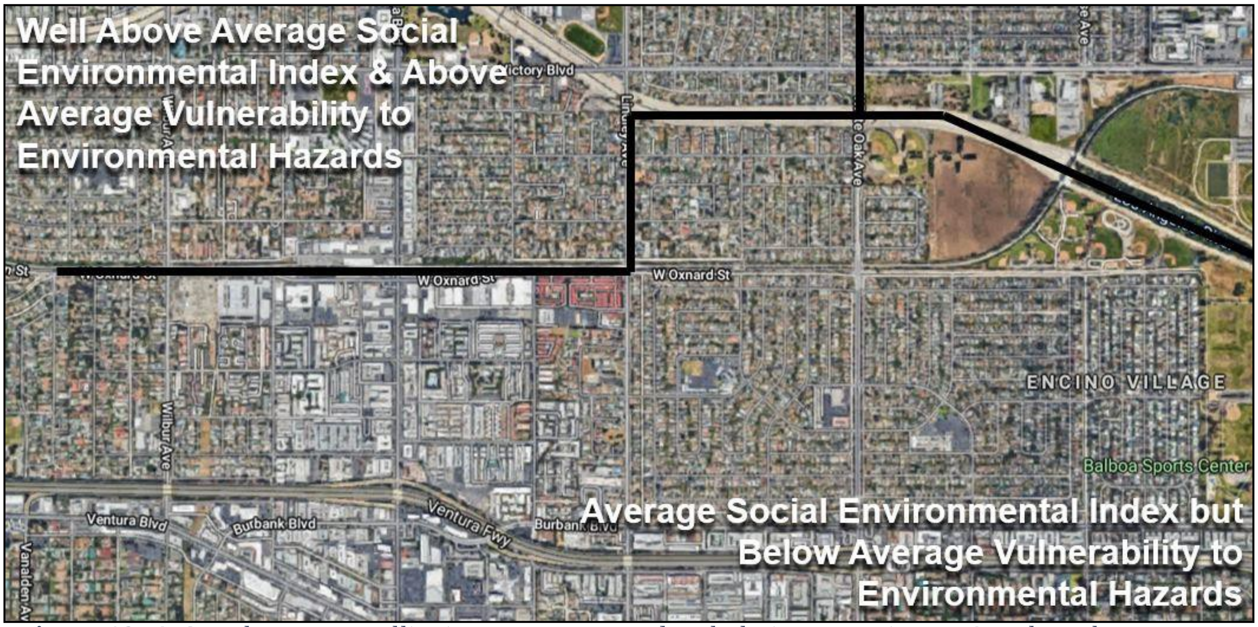

***Figure 18**: A Google Maps satellite image two ZIP code tabulation areas in Los Angeles. The two areas share similar development patterns of large residential neighborhoods adjacent to commercial corridors. The ZIP code tabulation area in the upper left is more vulnerable than the ZIP code tabulation area in the lower right.*

***Figure 19**: A Google Maps Street View image of a street located in a ZIP code tabulation area ranked above average in the social environmental index and well above average in the environmental hazard index. This image provides an example of the range of environmental hazards present in the build environment.*

Similar to the figures above, **Figure 20** and **Figure 21** illustrate the range in the estimated debris index through Google Maps Street View images. Areas with denser development patterns and older building construction have higher estimated debris index values than areas with less dense development and newer construction.

Figure 20*: A Google Maps Street View image of a street located in a ZIP code tabulation area with above average estimate debris. This street is an example of denser development of older construction in the City of Los Angeles.*

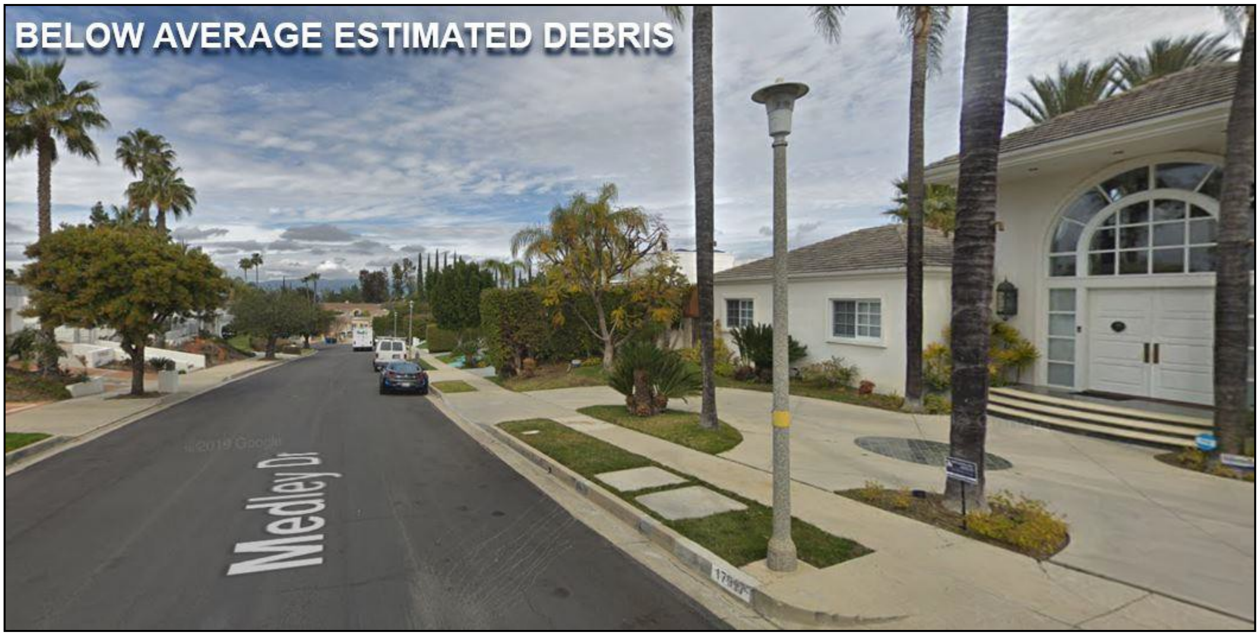

Figure 21*: A Google Maps Street View image of a street located in a ZIP code tabulation area with below average estimate debris. This street is an example of less dense development of newer construction in the City of Los Angeles.*

As discussed throughout this report, this project provides a vulnerability screening tool for analysts, public health officials, and emergency managers. The index is not a comprehensive study of all known environmental hazards, and the inclusion of additional hazards into the model may produce different results, increasing the vulnerability index in some neighborhoods and decreasing the vulnerability in others.

Additional Environmental Hazards for Consideration

The following categories of environmental hazards were identified during the hazard identification process; however, due to data limitations and project timeline constraints, they were not included in this version of the model. Future updates should consider incorporating one or more of the following hazards, but each will require additional research into data availability and sources.

Sewage Overflows

Sewage overflows can contaminate water supplies and the watersheds themselves. Storm surges can send sewage spilling back into roads and homes rather than being discharged directly to surface waters. This was encountered in Puerto Rico following Hurricane Maria.[39] Sewage can be a source of infectious disease and microscopic parasites that cause disease, such as cryptosporidiosis. People with decreased immunity are most at risk for severe disease associated with sewage exposure.[40]

Petroleum and Diesel Oil

In the aftermath of hurricanes Katrina and Rita, more than ten major (> 100,000 gallons) and medium (> 10,000 gallons) oil spills were reported along the coastal areas of Texas and Louisiana. The cumulative volume for these spills was approximately eight million gallons, which is just over half the volume of the Exxon Valdez event (1989).[41] The failure of a large above ground storage tank along the Elk River in West Virginia released 10,000 gallons of chemicals contaminating the City of Charleston's water supply.[42] These recent examples illustrate the vulnerability of storing petroleum, diesel, or other substances either above or below ground.

Many of these storage tanks are susceptible to failure during steady state and may be particularly vulnerable during a disaster. The EPA has a program to track and monitor leaking underground storage tanks;[43] however, the utility of this program during a catastrophic event, where normally intact storage may become compromised, is limited.

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[39] EPA Hurricane Maria Update, Friday January 5, 2018. (2018, January 05). Retrieved from https://www.epa.gov/newsreleases/epa-hurricane-maria-update-friday-january-5-2018

[40] Nemerow, N. L. (2009). Prevention and response to water-, food-, soil-, and air-borne disease and illness. Hoboken, NJ: Wiley.

[41] Farber, D. A., & Chen, J. (2006). Disasters and the law: Katrina and beyond. New York: Aspen.

[42] New York Times (January 10, 2014) accessed https://www.nytimes.com/2014/01/11/U.S./west-virginia-chemical-spill.html

[43] EPA. https://www.epa.gov/ust/underground-storage-tanks-usts-laws-and-regulations

Adverse health effects from oil spill exposure can occur, depending on what kind of oil was spilled and where (on land, in a river, or in the ocean). Other factors include what kind of exposure and how much exposure there was. Health effects from exposure to petroleum products vary depending on the concentration of the substance and the length of time that one is exposed.[44] Breathing petroleum vapors can cause nervous system effects (such as headache, nausea, and dizziness) and respiratory irritation. Very high exposure can cause coma and death. Liquid petroleum products which come in contact with the skin can cause irritation and some can be absorbed through the skin. Chronic exposure to petroleum products may affect the nervous system, blood and kidneys. Gasoline contains small amounts of benzene, a known human carcinogen.[45]

Potential Data Sources

EPA and state programs monitor, track, and regulate remediation of leaking underground storage tanks. There are numerous federal, state, and local databases to identify the location of these tanks.

Non-point source pollution/runoff

Non-point source (NPS) pollution results from land runoff, precipitation, atmospheric deposition, drainage, seepage, or hydrologic modification. The presence of NPS can be amplified during natural disasters, as seen following Hurricane Katrina.[46] According to the EPA,[47] NPS pollution, unlike pollution from industrial and sewage treatment plants, comes from many diffuse sources. Non-point source pollution is caused by rainfall and flood waters moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, depositing them into lakes, rivers, wetlands, coastal waters, and ground waters. NPS air pollution can also result from open sources, mobile sources, and natural sources. Man-made sources could be dust from farms, construction, and paved/unpaved roadways. Natural sources consist of emissions from vegetation, forest fires, and biological/geological sources.

The effects of nonpoint source pollutants on specific waters and human heath vary and may not always be fully identifiable or assessed. However, these pollutants have harmful effects on drinking water supplies, recreation, fisheries and wildlife.[48]

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[44] Oil Spills. (2019, April 03). Retrieved from https://medlineplus.gov/oilspills.html
[45] Toxic Substances Portal - Gasoline, Automotive. (2014, October 21). Retrieved from https://www.atsdr.cdc.gov/MMG/MMG.asp?id=465&tid=83
[46] Goldman, L., & Coussens, C. (2007). *Environmental public health impacts of disasters: Hurricane Katrina: Workshop summary*. Washington, D.C.: National Academies Press.
[47] Basic Information about Nonpoint Source (NPS) Pollution. (2018, August 10). Retrieved from https://www.epa.gov/nps/basic-information-about-nonpoint-source-nps-pollution
[48] Ibid.

GeoHealth Dashboard

The rapid advancement of web-based mapping and cloud computing have increased the accessibility to powerful data analysis and visualization tools for everyday consumers of spatial information, regardless of their level of training with traditional GIS software such as ArcGIS. Publishing the results of the model in a web-based mapping platform provides widespread access to this information. Future updates to data indicators or the methodology can be pushed out to users without the need to download updated versions of the tool and its results. Leveraging web-based mapping and cloud computing expands the reach of this analysis and allows users to observe and interact with the results at multiple resolutions, view data indicators separately, and select additional datasets to view simultaneously.

The results from the model are publicly available for viewing through HHS's web map platform, GeoHealth (https://geohealth.hhs.gov/arcgis/home). An interactive dashboard has been created allowing users to view each indicator as well as the composite index. An account is required to access the dashboard and is available to any individual who registers. GeoHealth was the selected platform because it is HHS's authoritative web mapping platform for the Office of the Assistant Secretary for Preparedness and Response (ASPR). A guide to accessing and using the dashboard are provided in **Appendix B**.

Testing the Model: Workshop Summary of Conclusions

Overview

The U.S. Department of Health and Human Services (HHS), Office of the Assistant Secretary for Preparedness and Response (ASPR), Recovery Division, conducted the Predictive Modeling for Environmental Health Recovery Workshop in Richmond, Virginia, on Monday June 24, 2019, from 0900 – 1300 EDT. The four-hour facilitated workshop engaged participants from the Los Angeles County Department of Public Health to explore the necessary and most useful inputs for local use of this tool and to test the pilot dashboard for its functionality and utility in meeting the public health emergency preparedness, response, and recovery needs of communities.

Joshua Barnes, Acting Director of the Recovery Division, HHS / ASPR provided the opening remarks and thanked the participants from Los Angeles for attending the workshop and providing candid input and an initial assessment of the tool. Scott Kaiser, HHS Support Team and GIS Analyst provided an overview of the project.

The project team presented the methodology and model outputs for the City of Los Angeles as well as demonstrated the GeoHealth dashboard to Los Angeles County Department of Public Health staff to facilitate feedback and comments on its potential usefulness and recommended improvements for future versions of the tool and dashboard.

The Los Angeles County Department of Public Health participants found broad utility in the tool as presented but had some valuable recommendations for further development and improvement of the tool in order to have direct applicability and use for their organization.

This Summary of Conclusions captures the workshop objectives, participants, and key discussion points, outcomes, and recommendations.

Objectives

- Demonstrate the capabilities of the pilot predictive modeling tool and dashboard to state and local-level public health officials
- Validate the model assumptions and outputs and receive user improvement recommendations to the methodology
- Evaluate the usefulness of the dashboard in state and local emergency preparedness, response and disaster recovery and its applicability to environmental and public health decision-making activities
- Determine the efficacy of the modeling tool for preparedness, response, and recovery planning and decision-making for public health officials
- Receive user improvement recommendations for the tool, methodology, and modeling assumptions

Discussion and Recommendations

Overall, participants found the tool to be potentially useful to decision-makers during the planning, response and recovery phases of a disaster. The ability to understand and see the co-location of environmental hazards and vulnerable populations was considered novel and helpful, especially when used in conjunction with other data layers and modeling tools. Indeed, it was emphasized that the tool would provide the most value when utilized in conjunction with existing disaster and environmental health modeling tools that model building damage, flooding, plume dispersion, earthquake impact, etc.

Participants emphasized the need to recognize the jurisdiction of the various organizations who may utilize this tool. As a county-level health department, it is vital that this data be available for the entire county (all 88 cities within the county) for the tool to prove useful. Furthermore, participants recognized that their ability to use the tool was reliant on a team of analysts familiar with GIS software and data analysis. The participants recognized that not all health departments and decision makers will have access to such resources (both personnel resources and technological resources) and emphasized is the importance of providing results in a format that could be immediately useful to those unfamiliar with GIS software or other data analysis methods. In addition, further guidance and use cases to help demonstrate the tools utilities were recommended and considered essential for the effective use of the tool.

A detailed list of all recommendations, considerations, and limitations is provided below.

Recommendations for GeoHealth Platform and ArcGIS tool

- Add ability to import additional data layers and export results for further analysis outside of the dashboard
- Include explanation of the results/values shown in the dashboard (e.g., percentile rank, crude prevalence, etc.)
- Revise labeling and symbology to emphasize the presence of low index values are not associated with an absence of vulnerability
- Consider potential fee-for-service model to provide health departments and other decision-making organizations with data and support
- Consider ability to carry out disaster-specific analysis

Additional Data to Consider

- Population and/or population density of ZIP code tabulation area and/or census tract
- Diurnal population change
- Railways, roads, ports, pipelines or other infrastructure which supports the manufacturing, distribution, or consumption of hazardous materials including the materials required to support the operation and maintenance of such infrastructure

- Age of infrastructure as an indicator of vulnerability
- Air and water quality data
- Environmental/geographic hazards including fire severity zones, flood hazards, coastal inundation, seismic hazards, etc.
- Electrical grid and transformers
- Land use
- Location of nuclear facilities and/or materials
- Location of extractive industries such as mining operations, oil and natural gas

Suggestions for Additional Materials and Guidance

- Population and/or population density of ZIP code tabulation area and/or census tract
- List of key questions to be considered during and post-disaster
- Guidelines and use cases to illustrate how these data could be utilized in various disaster scenarios including immediate, mid- and long-term recovery efforts
- Provide communication materials to guide analysts and decision-makers on how to communicate the results of the model and dashboard
- Make available the methodology behind the tool for reference
- Identify or connect to datasets and/or resources with information about adverse effects to public health from specific contaminants or hazards (e.g., TRACI v2.1)

Limitations Identified

- No ability to insert disaster-specific, location-specific, or real-time data sources into the model
- Utility of the dashboard may require human and analytic resources within health departments that may not be available to all agencies.
- The tool provides a static snapshot of pre-disaster vulnerability rather than predicting future public health outcomes
- Additional resources are required to conduct field sampling or the deployment of resources to vulnerable areas as identified by the model. Access to these resources may not always be available

Workshop Next Steps

Future funding will largely guide the next steps of the project, but the recommendations outlined above will be considered in identifying opportunities to build on the modeling framework, incorporate additional datasets where feasible, expand the dashboard functionality, and provide supplemental guidance for users of the tool.

Recommended Next Steps

Recommendations for next steps are divided into three categories—pilot next steps, exercise and workshop next steps, and technical next steps. Recommendations are not listed in order of priority and can be completed independent of other recommendations.

Pilot Recommended Next Steps

- Expand and test the model and methodology for suburban and rural geographies where datasets may be less robust and build in functionality to allow users to input their own local datasets, including hazardous facilities and building inventories.
- Incorporate additional environmental hazard data into the model, as identified in this report, prioritizing:
  - ✓ Hazardous waste disposal sites
  - ✓ Location of above ground and underground storage tanks
- Consider the value of integrating recent American Community Survey demographic data into the CDC's Social Vulnerability Index (SVI). CDC's SVI currently uses 2016 population estimates, but more recent data is available through the U.S. Census Bureau.
- Allow users to define the spatial resolution of the model results at either the ZIP code tabulation area or census tract.

Exercise/Workshop Recommended Next Steps

- Evaluate the feasibility of incorporating recommendations outlined in the planning workshop summary of conclusions.
- Explore the potential to integrate outputs from existing impact models such as Hazus.
- Expand the functionality and display of model results in the GeoHealth Dashboard based on recommendations and findings of the June 24 workshop, including:
  - ✓ Add an export function to allow users to export data in tabular format
  - ✓ Provide a series of use cases to illustrate how the information provided in the dashboard could be used by analysts and decision-makers

Technical Recommended Next Steps

- Operationalize the Toxic Release Inventory and Superfund application programming interfaces (APIs) within the model to enable use of the tool nationally and internally manage and summarize annual form R reports.

- Translate python script from Python 2.7 to Python 3 and modify GUI to run entirely as a standalone script tool available for use in ArcGIS Pro. As part of this migration, explore methods to optimize performance of the script to reduce geoprocessing time.
- Build in a function to allow users to specify their area of interest (e.g., scale the model for application beyond Los Angeles and the District of Columbia).

Appendix A: Glossary

Application Programming Interface (API)	• A set of definitions, communication protocols, and tools for building software.
GeoHealth Dashboard	• The dashboard is the primary way users will interact with the results of the model. The dashboard is hosted in GeoHealth and allows users to view a variety of information about the indices and the variables which went into this version of the model. The word "tool" can be used interchangeably with dashboard.
Disaster	• A serious disruption, occurring over a relatively short time, of the functioning of a community or a society involving widespread human, material, economic, or environmental loss and impacts that exceeds the ability of the affected community or society to cope using its own resources.
Disaster Recovery Environmental Hazard Index Model (Model)	• The model is the framework for evaluating known environmental hazards and contaminants to vulnerable populations as defined in the methodology. The model itself is an analytical framework that has been translated into a computer script to automate the analysis using the various datasets and sources identified in this version.
Environmental Hazard	• A substance, a state, or an event that has the potential to threaten the surrounding natural environment or adversely affect people's health.
Exposure	• An event during which individuals come into contact with a substance or agent. The duration of the event might be short or long, and the frequency might be continuous or periodic. The event might affect certain subgroups of the population based on characteristics such as geographic proximity or biological vulnerability. The response strategy to an exposure cannot be the same for all types of events or all population subgroups.
Exposure Pathway and Routes	• The means by which a person or population comes into contact with a hazardous substance. There are three basic exposure pathways: inhalation, ingestion, or direct contact.
Geographic Information Systems (GIS)	• A software program used to manage, manipulate, and analyze data that is directly or indirectly tied to a physical location on the earth.

Hazard Identification	• A process for enumerating the adverse health effects that might be caused by exposure to some substance, state, or event and characterizing the quality and weight of evidence supporting the assessment.
Medically Vulnerable Populations	• Vulnerable populations include the economically disadvantaged, racial and ethnic minorities, the uninsured, low-income children, the elderly, the homeless, those with human immunodeficiency virus (HIV), and those with other chronic health conditions, including severe mental illness.
Risk Characterization	• The judgement of the nature and presence or absence of risks, along with information about how the risk was assessed, where assumptions and uncertainties still exist, and where policy choices will need to be made.
Risk of Adverse Response	• The potential loss of life, injury, or destroyed or damaged assets that could occur to a system, society, or a community in a specific period, determined probabilistically as a function of hazard, exposure, and vulnerability/capacity.
Vulnerability to Exposure	• The potential for a population exposure to a known environmental hazard as a result of a disturbance to the built environment that otherwise would not occur during a normal, steady state.
Zip Code Tabulation Area	• A U.S. Census Bureau geographic unit defined as a generalized areal representation of United States Postal Service ZIP code service areas.

Appendix B: GeoHealth Dashboard User Guide

1. The results of the disaster recovery environmental hazard index can be viewed through a publicly open dashboard hosted on the GeoHealth platform (https://geohealth.hhs.gov/arcgis/home).
2. The dashboard can be accessed at: https://geohealth.hhs.gov/arcgis/apps/opsdashboard/index.html#/dc027151600e4cc9a95b172a7a228189
3. Access to the dashboard requires a GeoHealth account which is available upon request. To request an account visit https://geohealth.hhs.gov/arcgis/home/ and click "apply for accounts" at the bottom of the page.
4. Navigate to the content page and using the search bar in the upper right, search "Disaster Recovery Environmental Hazard Index" for apps.

***Figure 22**: Screenshot of GeoHealth landing page*

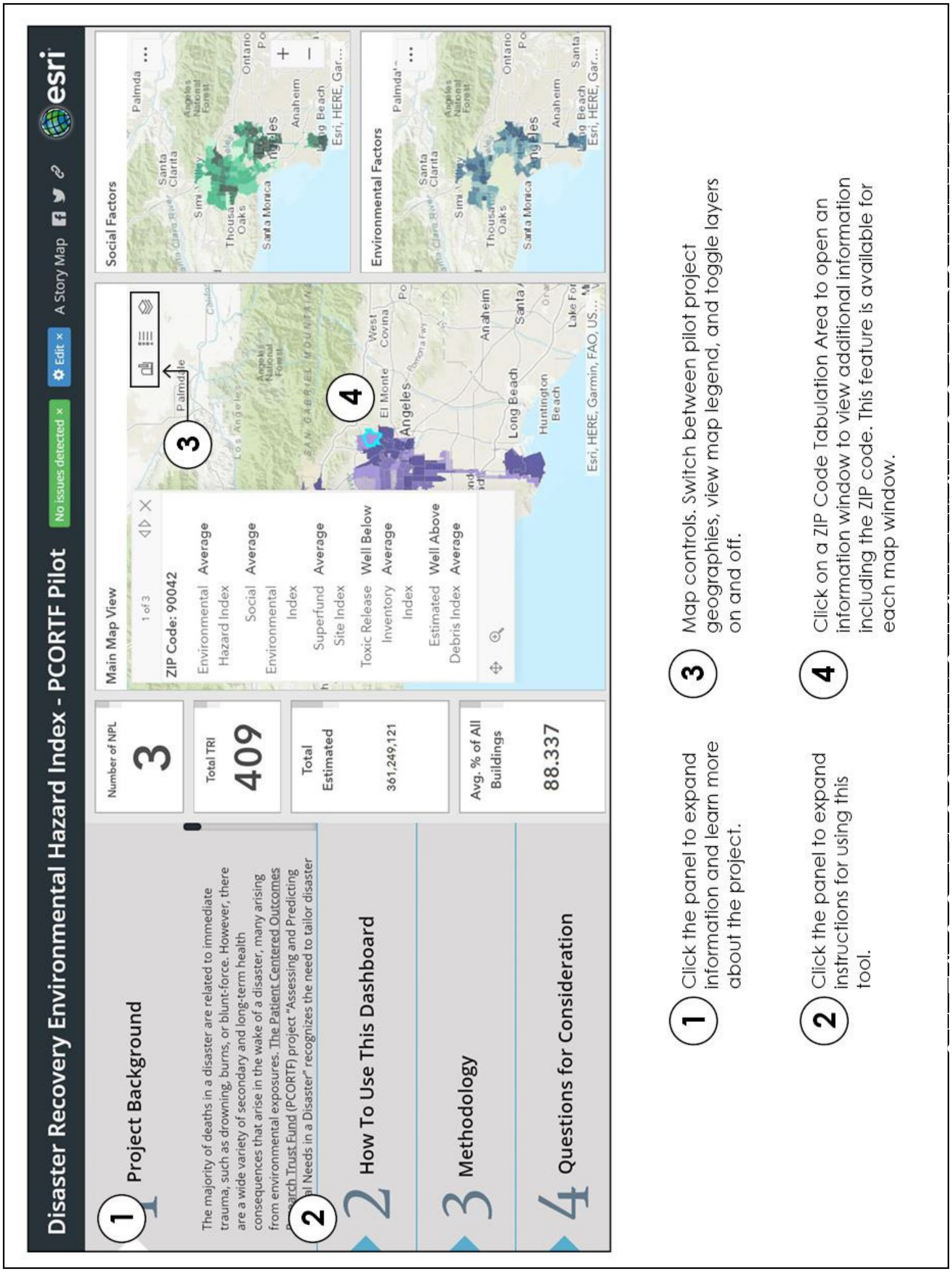


***Figure 23**: Dashboard user guide highlighting important functions and operability*

Appendix C: Questions for Analysts and Decision-makers

The following environmental health and hazard related questions are provided to help analysts, local and state public health officials use the indicators and results of the disaster recovery environmental hazard index in the decision-making process in disaster preparedness, response and recovery. When asked in conjunction with viewing the index, these questions can help organize next steps for decision-makers and identify appropriate resources whether that be additional environmental testing or modeling, risk communications, or long-term recovery needs assessments. The following list is not all inclusive and additional questions should be asked when determining courses of action during a public health emergency. The list is not sequential and questions can be asked in any order. The questions are broadly grouped into preparedness, response and recovery, all phases of emergency management, and natural resources.

General Questions

- Where are the environmental hazards located in the jurisdiction?
- What are the types of environmental hazards in your jurisdiction?
  - ✓ Chemical (single or multiple/cumulative risk)
  - ✓ Radiological
  - ✓ Physical (dust, heat)
  - ✓ Microbiological or biological
- Do the environmental hazards originate from or are released from a single point (point source)?
- Are the environmental hazards non-point specific (non-point source)?
- Is the environmental hazard from a natural source (e.g., radon)?
- What storage method(s) are containing these hazards during a steady state environment (e.g., surface impoundments, above ground or underground storage tanks, sealed barrels, containment buildings, etc)?
- How could sewage treatment (onsite, private, and municipal) facilities be impacted by a disaster?
- How could storm water management (onsite, private, and municipal) facilities be impacted by a disaster?
- Have safe distances from sites with environmental hazards been identified?
- How likely is it that an environmental hazard could encounter stored or prepositioned equipment, materials, and provisions vital to disaster response and recovery?
- Is a plan in place to test for possible contamination of equipment, materials, and provisions vital to disaster response and recovery?

- If an environmental hazard threatens or could threaten primary places of refuge, shelters, and evacuation routes, have safer alternatives been identified?
- Have decontamination procedures at shelters been established?

Preparedness

- What special knowledge or training in hazardous waste operations and emergency response training is needed by responders?
- What special knowledge or training is needed for emergency medical personnel given the presence of environmental hazards?
- What special knowledge or training in hazardous waste operations and emergency response training is needed by recovery personnel?
- Have environmental testing equipment, methods and facilities been pre-identified to allow for rapid impact assessments?
- Does the jurisdiction have the human and technical capacity to quickly (at the time of, and immediately following, the disaster) obtain data on soil, air, water impacts to assess risk and define the magnitude of affected area?
- Have specific procedures for reentering facilities with environmental hazards during and following disasters been established?
- Have hazard specific appendices been developed for the jurisdiction's emergency preparedness and response plans?
- Have sites for the storage of potentially contaminated disaster debris (e.g., building materials, soil, and sediment) been identified?
- Are environmental health specialists included in emergency planning, response, and recovery operations and discussions?
- Does the jurisdiction have the capacity to rapidly conduct environmental health and sanitation inspections (e.g., of drinking water, storm water, onsite and public sewer, food establishments, and housing) following the disasters?

Response and Recovery

- Has a hazard analysis (e.g., hazard identification, vulnerability analysis, and risk analysis) been conducted?
- Is it possible that the environmental hazards could become fugitive (e.g., storage tanks that migrate or change locations)?
- What could cause the environmental hazard to become fugitive?
- How likely is it that the environmental hazard could become fugitive?

- What is the nature of the hazardous material [e.g., flammable, corrosive, unstable (may react violently when heated, compressed, or brought into contact with water) and/or poisonous]?
- Is the mixing of incompatible hazardous materials/wastes possible (i.e., hazards that will undergo a chemical reaction if they encounter one another)?
- Could the mixing or interaction of two or more environmental hazards present a greater or unexpected hazard?
- Who is at risk of exposure to the environmental hazards?
  - ✓ Individuals
  - ✓ General population
  - ✓ Life stages (e.g., very young, pregnant or nursing women, very old)
  - ✓ Highly susceptible (e.g., those with asthmas, compromised immune systems)
  - ✓ Highly exposed (e.g., based on geographic proximity, occupation, housing, mobility, access to resources, and economic status)
- How does human exposure to the environmental hazards occur?
  - ✓ Pathways (one or more may be involved)
    - ▪ Air
    - ▪ Surface Water
    - ▪ Groundwater
    - ▪ Soil/Sediment
    - ▪ Solid Waste/Debris
    - ▪ Food
    - ▪ Non-food consumer products, pharmaceuticals that may be contaminated
  - ✓ Routes (and related human activities that lead to exposure)
    - ▪ Ingestion (both food and water)
    - ▪ Contact with skin
    - ▪ Inhalation
    - ▪ Non-dietary ingestion (for example, "hand-to-mouth" behavior)
- How does the environmental hazard, exposure route, and pathway change over time (e.g., contaminated sediment can turn to dust changing exposure route from contact with skin to inhalation)?
- How does the human body respond to or process the environmental hazard? How is this impacted by factors such as age, sex, genetics, etc.?)
  - ✓ Absorption: does the body take up the environmental hazard
  - ✓ Distribution: does the environmental hazard travel throughout the body or does it stay in one place?
  - ✓ Metabolism: does the body break down the environmental hazard?
  - ✓ Excretion: how does the body get rid of it?
- What are the human health effects of the environmental hazard?
  - ✓ Are the effects short term (right away or a few hours to a day from exposure)?
  - ✓ Are the effects long term?

- How long does it take for an environmental hazard to cause a toxic effect?
  - ✓ Acute
  - ✓ Subchronic - weeks or months (for humans generally less than 10% of their lifespan)
  - ✓ Chronic - a significant part of a lifetime or a lifetime (for humans at least seven years)
  - ✓ Intermittent
- At what dose, degree, or extent of exposure does the environmental hazard become a human health concern?
- Is there a critical time during a lifetime when an environmental hazard is most toxic (e.g., fetal development, childhood, during aging)?
- How will places of refuge, shelters, and evacuation routes be impacted by the environmental hazard?
- Has an inspection team (or teams) been appointed to determine when a site is safe for recovery operations?

Natural Resources

- Has the geology and soil morphology in and around environmental hazard sites been determined?
- How might surface water and ground elevation characteristics influence the movement of hazards within the jurisdiction?
- Will the release of the hazardous material threaten private and public water supplies?
- Will the release of the hazardous material threaten aquatic (marine or freshwater) ecosystems?
- Has the estimated seasonal high ground water in and around environmental hazard sites been determined?
- Is the hazard site proximal to a shallow water table?

Appendix D: Python Script User Guide

The script used to carry out this analysis was written in Python 2.7 and utilizes the ArcGIS "arcpy" python module as well as a number of other Python modules. These modules are premade tools to carry out specialized mathematical and spatial calculations and are required for the code to run successfully. Specific software and python modules are required to be installed on the computer where the model will run.

Required Software

- ESRI ArcGIS Desktop 10.x (ArcMap) with the Spatial Analyst Extension
- Python 2.7
- PythonWin or PyScriptor
- Pip or Anaconda

Installation

An ArcGIS license and a windows machine is required to install ArcGIS Desktop. Instructions for how to install and configure the ArcGIS application can be found on the ArcGIS website. Along with this ArcGIS installation, Python 2.7 will install automatically.
PythonWin is a code editing program made specifically for writing and testing python scripts. Instructions for how to install PythonWin can be found online at several sources. We recommend these instructions from Penn State. Pip and/or Anaconda are programs used to install and manage Python modules. Both can be installed from the command line of your computer or downloaded as a program. It should be noted that when installing PythonWin, the program should be installed within the ArcGIS folder within your Python27 folder (for example: C:\Python27\ArcGIS10.6).

In addition to the software mentioned above, this script requires additional Python modules. These modules can be thought of as tools in a toolbox. While some of the modules are automatically downloaded when Python is installed, others require separate installation.

To inspect which modules are already installed on your computer, open PythonWin or PyScriptor. Type "Import" followed by the module name and hit enter. If the module is installed, your cursor will move to the next line and no message will be returned. If the module is not installed, a message will be returned informing you the module is not recognized. To install python modules, follow the instructions below:

1. Open the Start Menu and search "cmd"
2. Select Command Prompt
3. When the command prompt window opens, the file path for your working directory will likely be set to the default, your user account file. Change the file path to direct the

computer to install the python modules in the python scripts folder. The python scripts folder can be found at C:\Python27\ArcGIS10.6\Scripts

4. Copy the file path. You are now ready to install the python modules.
5. Type "cd\" and press enter
6. Type "cd C:\Python27\ArcGIS10.6\Scripts" (Replace the path shown here with the path you copied in Step 4)
7. Type "pip install" followed by the name of the python module and press enter. The python module is successfully installed. If you are using Anaconda as your module management software, replace "pip install" with the Anaconda prompt, "conda install" followed by the name of the module.

A complete list of the python modules required to run this tool:

- ✓ arcpy
- ✓ requests
- ✓ tkFileDialog
- ✓ tkinter
- ✓ urllib2
- ✓ pandas
- ✓ os
- ✓ sys
- ✓ numpy
- ✓ json
- ✓ Dbf5 from simpledbf
- ✓ openpyxl

As stated previously, many of these modules may already be installed on your machine, but it is important to guarantee all are installed for the entirety of the script to run smoothly.

RUNNING THE SCRIPT

After you have all necessary software and modules installed, you are ready to run the script. Follow these steps to run the script:

1. Open **PythonWin** or **PyScripter**
2. Go to **File** > **Open** and navigate to the **Environmental Hazard Index Script**
3. Make sure the **Environmental Hazard Index Script** window is active within the program and press **Run** located in the toolbar at the top of the window.
4. In the **Arguments** line, type the name of the field which contains the construction year for the building data (for Los Angeles it is "YearBuilt1" and for the District of Columbia it is "MapYear"). This is case sensitive.
5. Click **Run**

It may take up to 30 minutes or more depending on your computer's processing speed for the model to run in its entirety due to file size of specific data layers used in the model. Once the tool is finished, a message will be returned at the bottom of the screen reading, "Script returned exit code 0". This message indicates the script ran successfully. The file output from the analysis is automatically saved in the same file where the Environmental Hazard script is saved to your computer.

Appendix E: Workshop Participants

- Patrick Ashley, Virginia Department of Health
- Joshua Barnes, HHS/ASPR
- Dee Bagwell, Loc Angeles County Department of Public Health
- Christiana Briggs, HHS/ASPR Support Team
- Leremy Colf, HHS/ASPR
- Brandon Dean, Los Angeles County Department of Public Health
- Scott Kaiser, HHS/ASPR Support Team
- Casey Kalman, HHS/ASPR Support Team
- Jee Kim, Los Angeles County Department of Public Health
- Robert Mauskapf, Virginia Department of Health
- Suzanne Silverstein, Virginia Department of Health
- Justin Snair, HHS/ASPR Support Team

Appendix F: Disaster Recovery Environmental Hazard Index Metadata

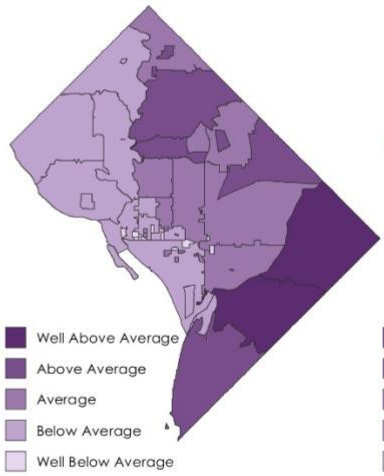
FIELD NAME	FIELD TYPE	DESCRIPTION	SOURCE
ZCTA5CE10	STRING	5-Digit Zip Code Tabulation Area	
SVI	DOUBLE	Original CDC SVI aggregated to the ZCTA level	CDC
SVI_PLS1	DOUBLE	CDC Asthma Prevalence (Estimated) (Percentile Rank)	ASPR (Calculated in Model)
SVI_PLS2	DOUBLE	COPD Prevalence (Estimated) (Percentile Rank)	ASPR (Calculated in Model)
SVI_PLS3	DOUBLE	Cancer Prevalence (Estimated) (Percentile Rank)	ASPR (Calculated in Model)
SVI_PLS4	DOUBLE	Hypertension Prevalence (Estimated) (Percentile Rank)	ASPR (Calculated in Model)
SVI_PLS5	DOUBLE	Mental Health Prevalence (Estimated) (Percentile Rank)	ASPR (Calculated in Model)
SVI_PLS6	DOUBLE	emPOWER Electricity Dependent Durable Medical Equipment (Percentile Rank)	HHS emPOWER - ASPR (Calculated in Model)
SVI_PLS7	DOUBLE	Nursing Home Capacity (Percentile Rank)	ASPR (Calculated in Model)
SVI_PLS8	DOUBLE	Correctional Facility Capacity (Percentile Rank)	ASPR (Calculated in Model)
SVI_PLS9	DOUBLE	Emergency Evacuation Shelter Capacity (Percentile Rank)	ASPR (Calculated in Model)
SVI_PLS10	DOUBLE	Homeless Shelter Count (Percentile Rank)	ASPR (Calculated in Model)
SVI_PLS11	DOUBLE	Population 65 and Older Living Alone (Percentile Rank)	ASPR (Calculated in Model)
COUNT_1	LONG	Count of Nursing Homes per ZCTA	CMS
COUNT_2	LONG	Count of Correctional Facilities per ZCTA	HIFLD
COUNT_3	LONG	Count of Homeless Shelters per ZCTA	City Portal Data
COUNT_4	LONG	Count of Emergency Evacuation Shelters per ZCTA	HIFLD
POP_1	LONG	Nursing Home Certified Resident Capacity	CMS
POP_2	LONG	Correctional Facility Total Population	HIFLD
POP_3	LONG	Emergency Evacuation Shelter Capacity	HIFLD
POP_4	DOUBLE	CDC Asthma Prevalence (Estimated Crude Prevalence)	CDC
POP_5	DOUBLE	COPD Prevalence (Estimated Crude Prevalence)	CDC
POP_6	DOUBLE	Cancer Prevalence (Estimated Crude Prevalence)	CDC
POP_7	DOUBLE	Hypertension Prevalence (Estimated Crude Prevalence)	CDC

FIELD NAME	FIELD TYPE	DESCRIPTION	SOURCE
POP_8	DOUBLE	Mental Health Prevalence (Estimated Crude Prevalence)	CDC
POP_9	DOUBLE	Population 65 and Older Living Alone as Percentage of Total Households per ZCTA	ACS
SEI_RANK	DOUBLE	Social Environmental Index (Percentile Rank)	ASPR (Calculated in Model)
SF_1	LONG	Count of National Priority List (NPL) Superfund Sites per ZCTA	EPA
SF_2	LONG	Count of Non-National Priority List (Non-NPL) Superfund Sites per ZCTA	EPA
SF_3	DOUBLE	Average distance (meters) to a NPL Superfund Site from any location within a ZCTA	ASPR (Calculated in Model)
SF_4	DOUBLE	Average distance (meters) to a Non-NPL Superfund Site from any location within a ZCTA	ASPR (Calculated in Model)
SF_RANK	DOUBLE	Superfund (NPL & Non-NPL) Rank (Percentile Rank)	ASPR (Calculated in Model)
TRI_1	LONG	Count of Toxic Release Inventory (TRI) Facility per ZCTA	EPA
TRI_2	DOUBLE	Average distance (meters) to a TRI Facility from any location within a ZCTA	ASPR (Calculated in Model)
TRI_RANK	DOUBLE	Toxic Release Inventory Rank (Percentile Rank)	ASPR (Calculated in Model)
BLD_1	LONG	Estimated tons of building debris per ZCTA	City Poral Data - ASPR (Calculated in Model) - Modified from USGS equation
BLD_2	DOUBLE	Percent of building stock per ZCTA constructed prior to 1978	City Portal Data - ASPR (Calculated in Model)
BLD_3	DOUBLE	Percent of building stock per ZCTA constructed prior to 1980	City Portal Data - ASPR (Calculated in Model)
BLD_RANK	DOUBLE	Building Debris, Lead and Asbestos Prevalence Rank (Percentile Rank)	ASPR (Calculated in Model)
EHI_RANK	DOUBLE	Disaster Recovery Environmental Hazard Index (Percentile Rank)	ASPR (Calculated in Model)

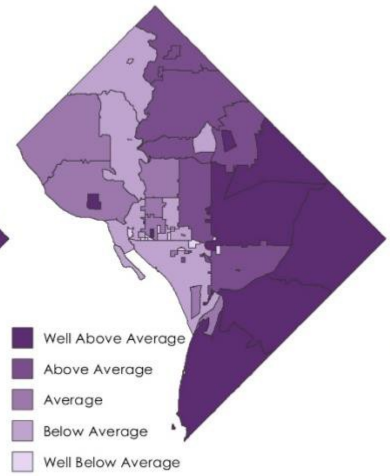
Appendix G: Mapping the Model Indicators (District of Columbia)

The following series of 38 maps for the District of Columbia provides an independent view of each of the variables included in the disaster recovery environmental hazard index and the fields provided in the output feature class published to GeoHealth and available for viewing through the project dashboard (see Appendix B). The majority of maps are shown as a percentile rank by ZIP code tabulation area, translated to a vulnerability scale between "well below average" and "well above average." In some cases, raw values are included where we believe the raw value may benefit analysts and public health professionals. The health indicators are presented as percentile rank and raw prevalence rates (provided as a floating data type).

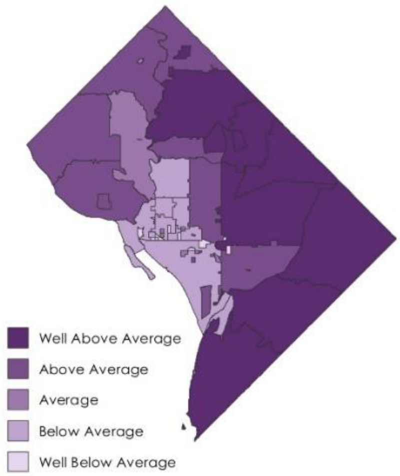
Aggregated SVI



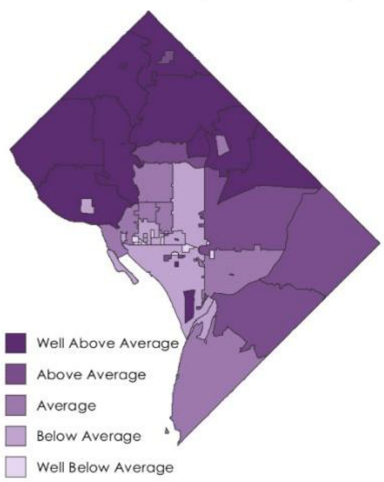
Asthma Prevalence (Percentile Rank)



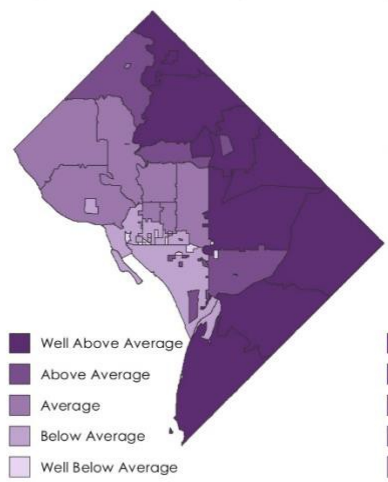
COPD Prevalence (Percentile Rank)



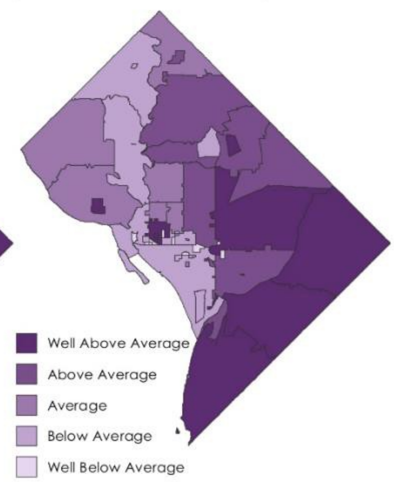
Cancer Prevalence (Percentile Rank)



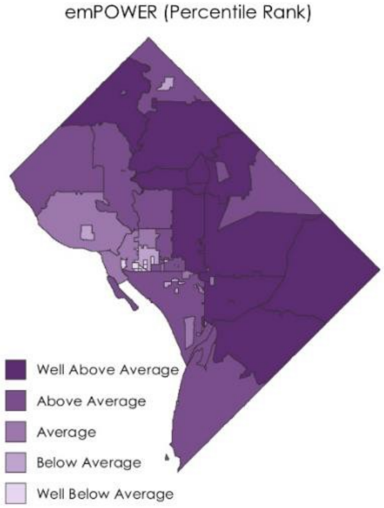
Hypertension Prevalence (Percentile Rank)



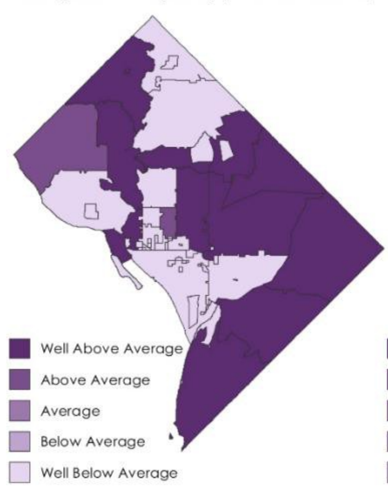
Mental Health Prevalence (Percentile Rank)



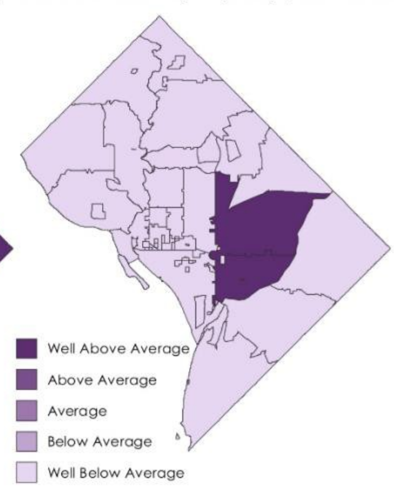
emPOWER (Percentile Rank)



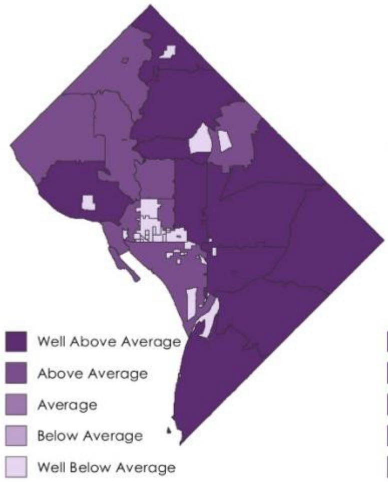
Nursing Home Capacity (Percentile Rank)



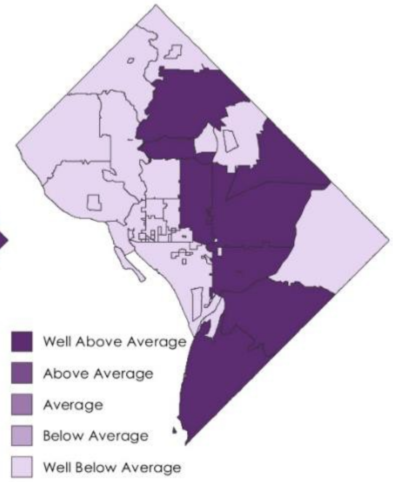
Correctional Facility Capacity (Percentile Rank)



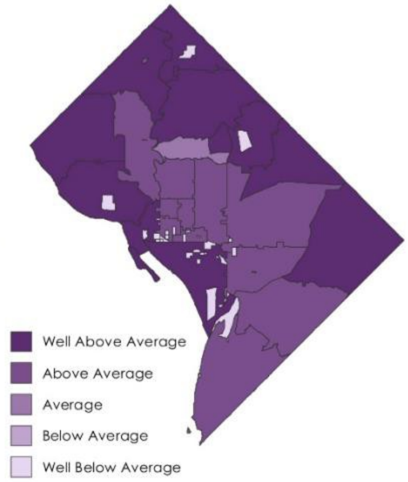
Emg Evacuation Shelters (Percentile Rank)



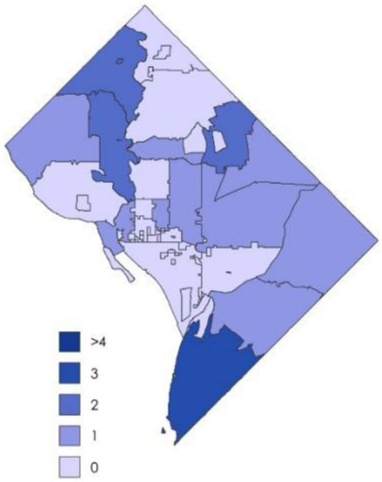
Homeless Shelter Capacity (Percentile Rank)



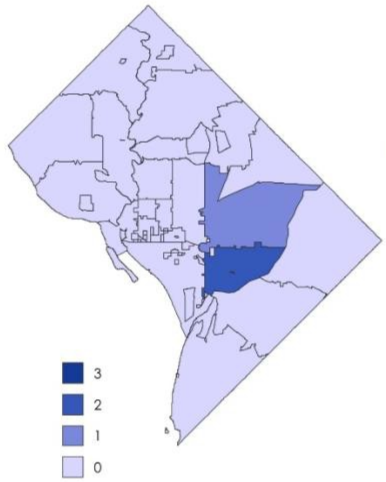
Pop 65+ Living Alone (Percentile Rank)



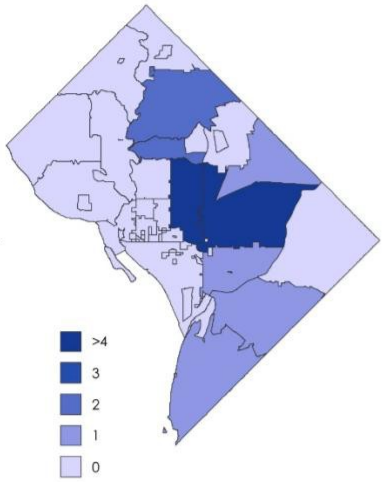
Nursing Home Facilities (Count)



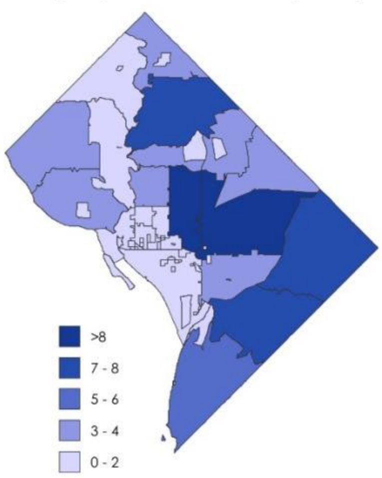
Correctional Facilities (Count)



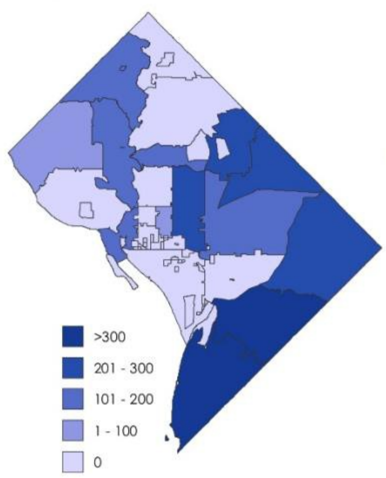
Homeless Shelters (Count)



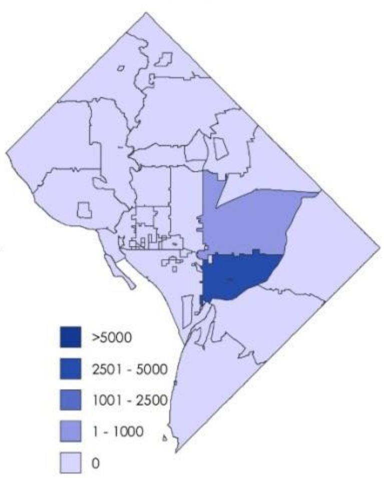
Emergency Evacuation Shelters (Count)

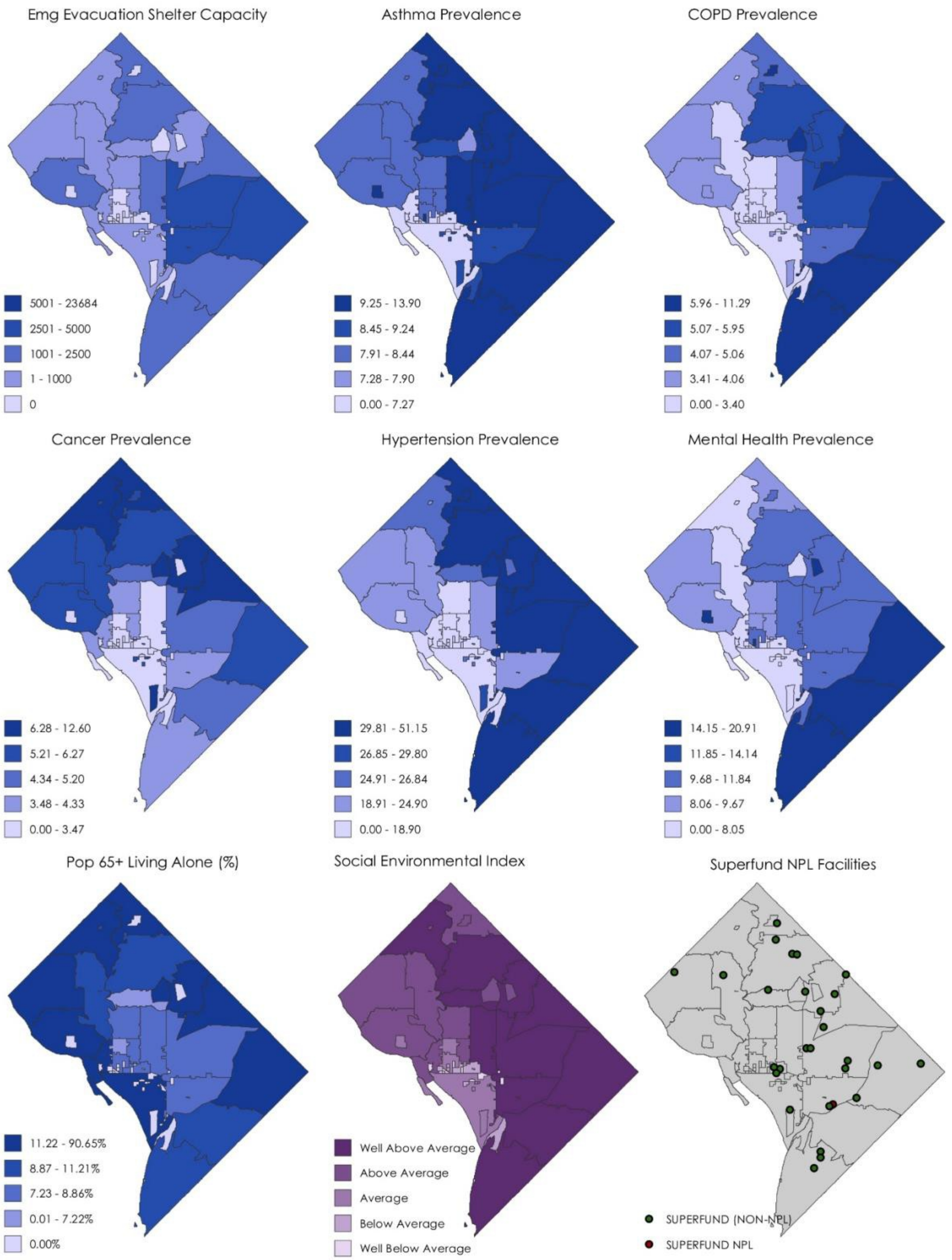


Nursing Home Capacity (Population)

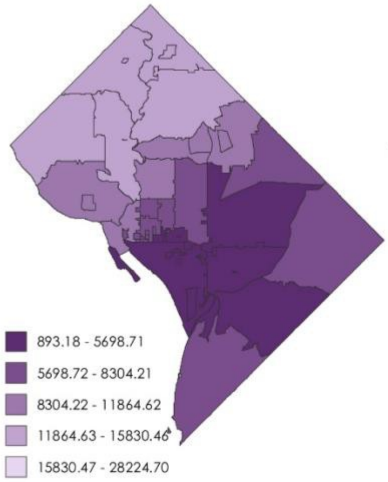


Correctional Facility Capacity (Population)

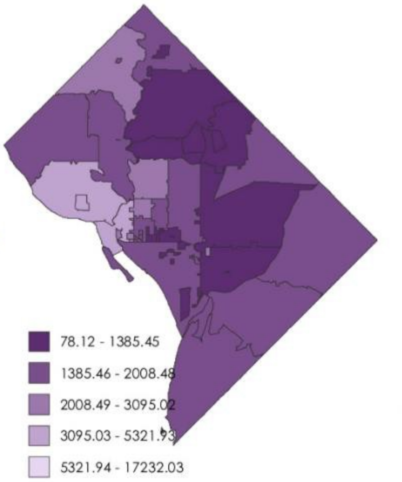



Emg Evacuation Shelter Capacity
5001 - 23684
2501 - 5000
1001 - 2500
1 - 1000
0
Asthma Prevalence
9.25 - 13.90
8.45 - 9.24
7.91 - 8.44
7.28 - 7.90
0.00 - 7.27
COPD Prevalence
5.96 - 11.29
5.07 - 5.95
4.07 - 5.06
3.41 - 4.06
0.00 - 3.40
Cancer Prevalence
6.28 - 12.60
5.21 - 6.27
4.34 - 5.20
3.48 - 4.33
0.00 - 3.47
Hypertension Prevalence
29.81 - 51.15
26.85 - 29.80
24.91 - 26.84
18.91 - 24.90
0.00 - 18.90
Mental Health Prevalence
14.15 - 20.91
11.85 - 14.14
9.68 - 11.84
8.06 - 9.67
0.00 - 8.05
Pop 65+ Living Alone (%)
11.22 - 90.65%
8.87 - 11.21%
7.23 - 8.86%
0.01 - 7.22%
0.00%
Social Environmental Index
Well Above Average
Above Average
Average
Below Average
Well Below Average
Superfund NPL Facilities
SUPERFUND (NON-NPL)
SUPERFUND NPL

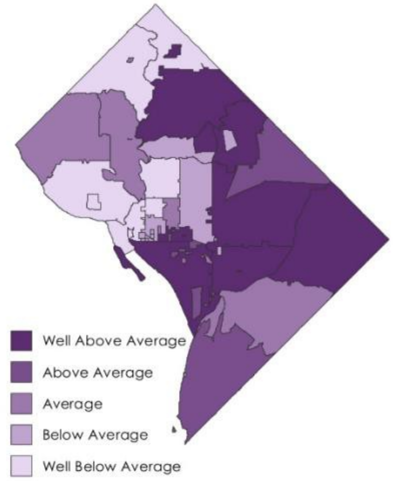
NPL Average Distance (meters)



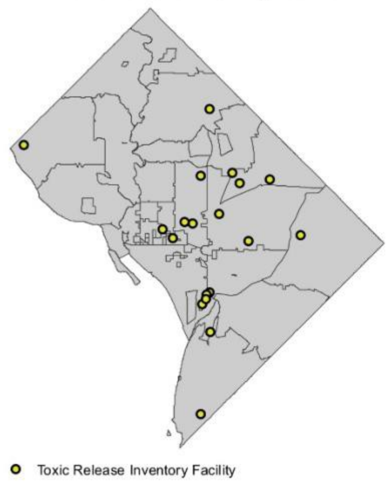
Non-NPL Average Distance (meters)



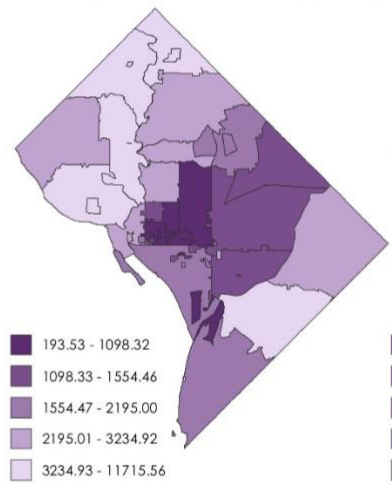
Superfund Index



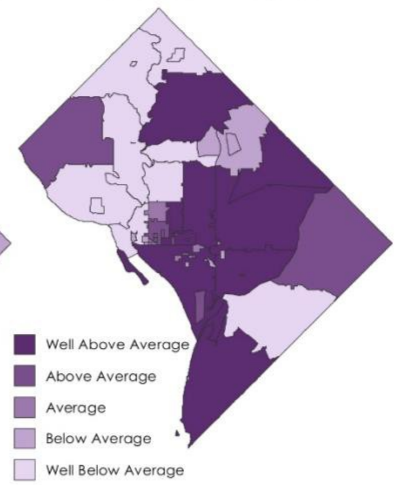
Toxic Release Inventory Facilities



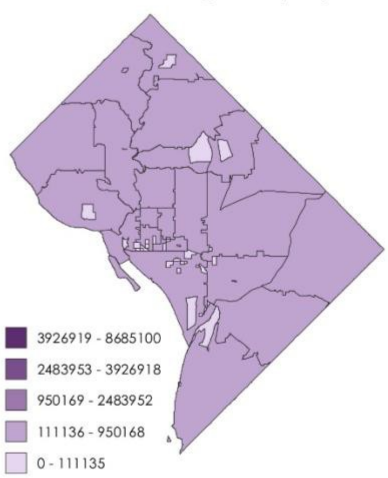
Avg Distance to TRI Facility (meters)



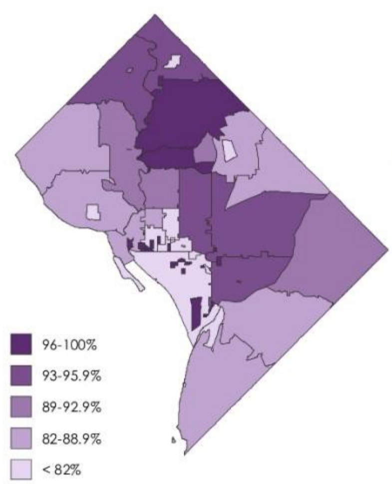
Toxic Release Inventory Index



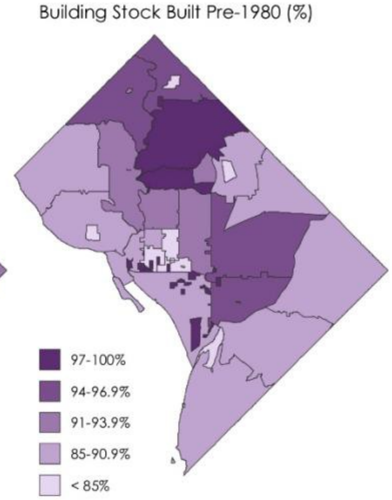
Estimated Building Debris (tons)

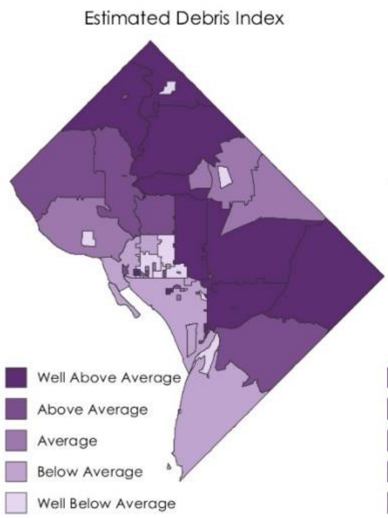


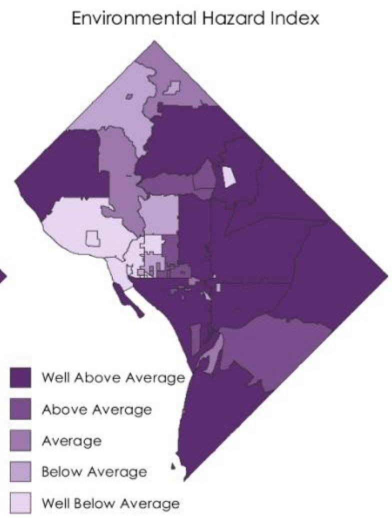
Building Stock Built Pre-1978 (%)



Building Stock Built Pre-1980 (%)



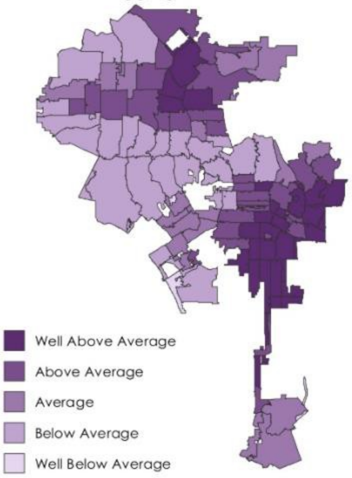

Estimated Debris Index
Well Above Average
Above Average
Average
Below Average
Well Below Average


Environmental Hazard Index
Well Above Average
Above Average
Average
Below Average
Well Below Average

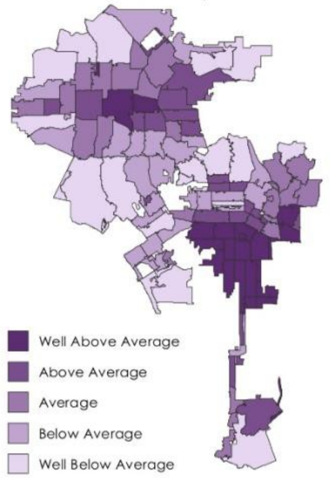
Appendix H: Mapping the Model Indicators (Los Angeles)

The following series of 38 maps for the City of Los Angeles provides an independent view of each of the variables included in the disaster recovery environmental hazard index and the fields provided in the output feature class published to GeoHealth and available for viewing through the project dashboard (see Appendix B). The majority of maps are shown as a percentile rank by ZIP code tabulation area, translated to a vulnerability scale between "well below average" and "well above average." In some cases, raw values are included where we believe the raw value may benefit analysts and public health professionals. The health indicators are presented as percentile rank and raw prevalence rates (provided as a floating data type).

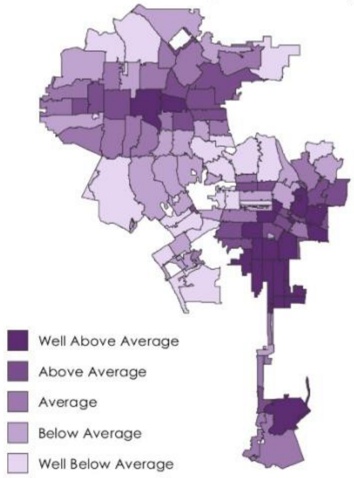
Aggregated SVI



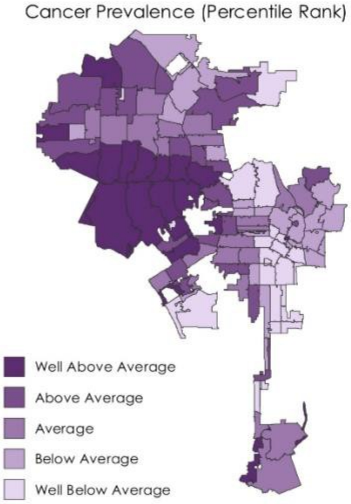
Asthma Prevalence (Percentile Rank)



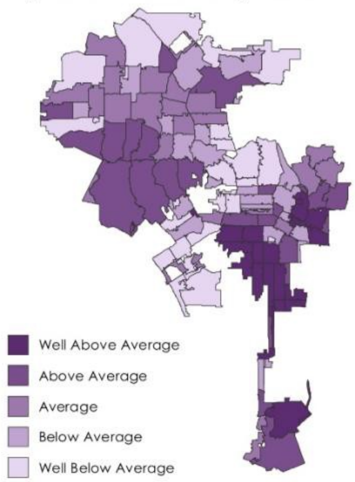
COPD Prevalence (Percentile Rank)



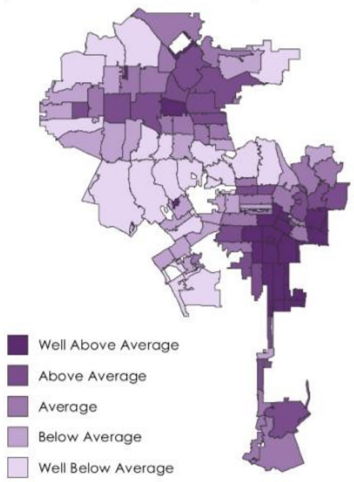
Cancer Prevalence (Percentile Rank)



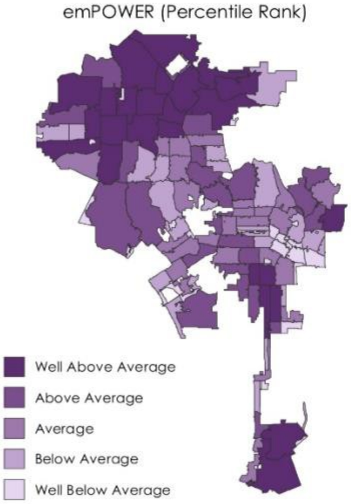
Hypertension Prevalence (Percentile Rank)



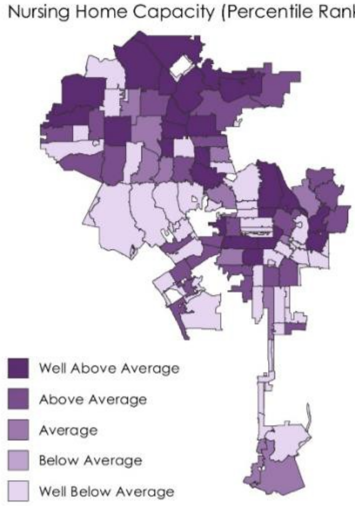
Mental Health Prevalence (Percentile Rank)



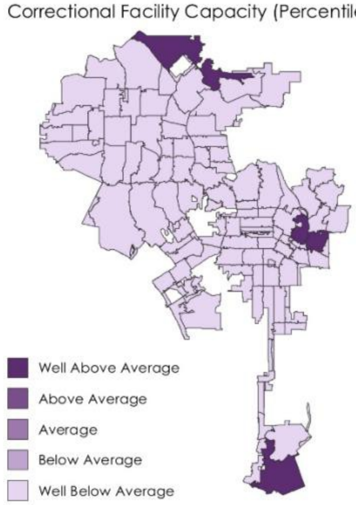
emPOWER (Percentile Rank)



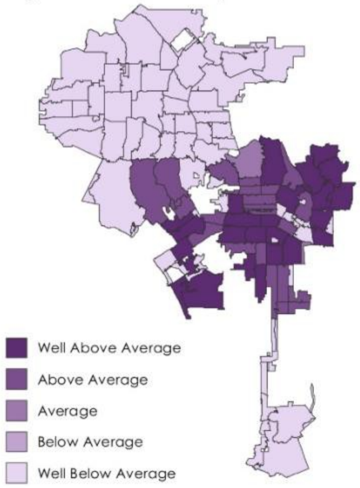
Nursing Home Capacity (Percentile Rank)



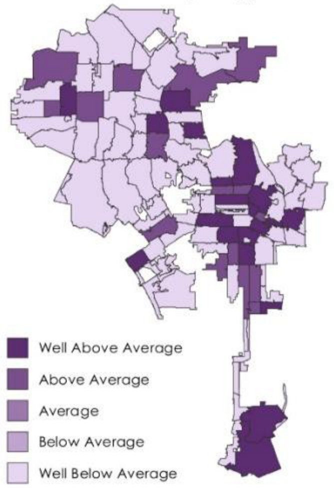
Correctional Facility Capacity (Percentile Rank)



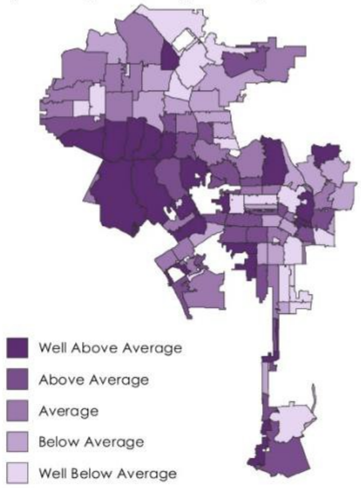
Emg Evacuation Shelters (Percentile Rank)



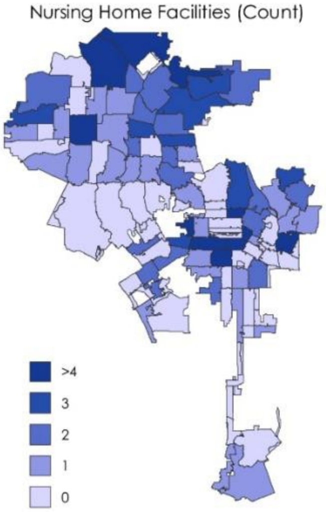
Homeless Shelter Capacity (Percentile Rank)



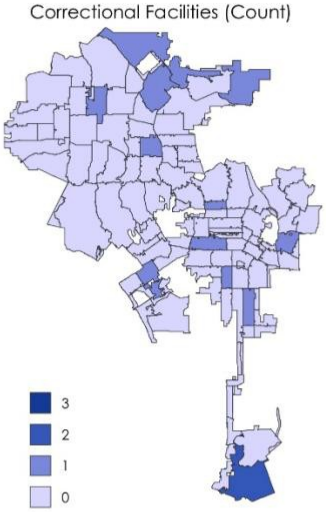
Pop 65+ Living Alone (Percentile Rank)



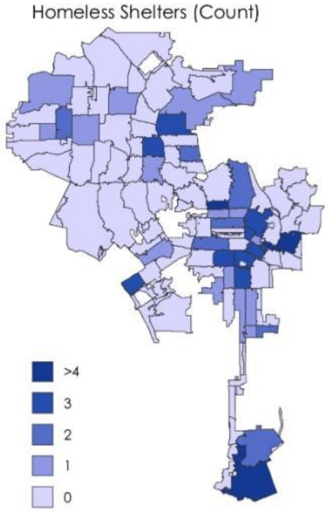
Nursing Home Facilities (Count)



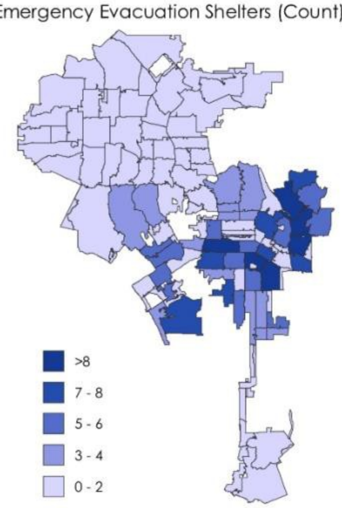
Correctional Facilities (Count)



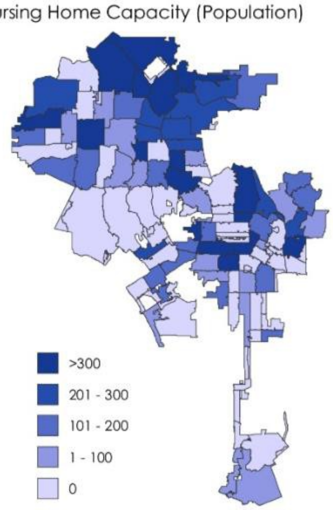
Homeless Shelters (Count)



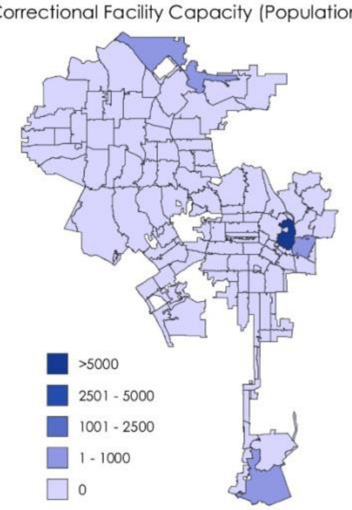
Emergency Evacuation Shelters (Count)



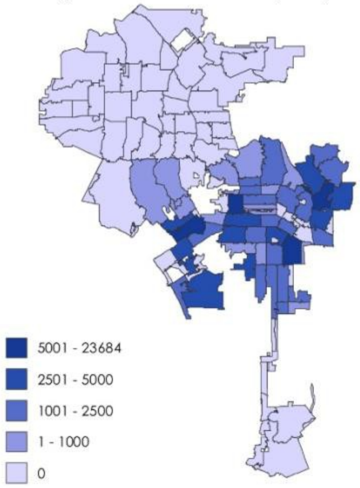
Nursing Home Capacity (Population)



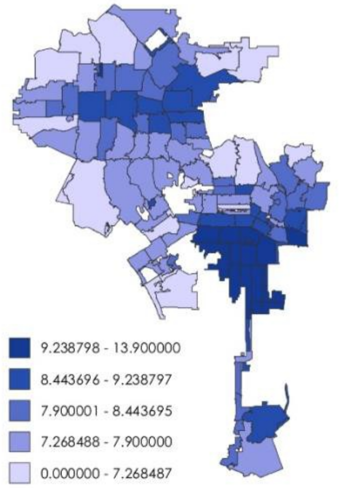
Correctional Facility Capacity (Population)



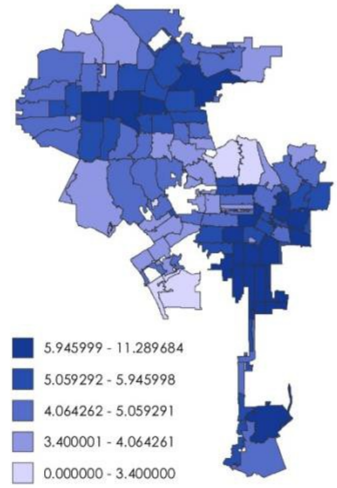
Emg Evacuation Shelter Capacity



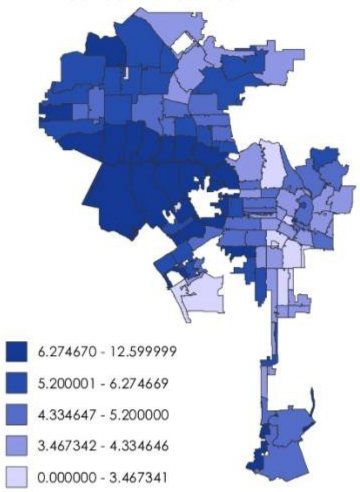
Asthma Prevalence



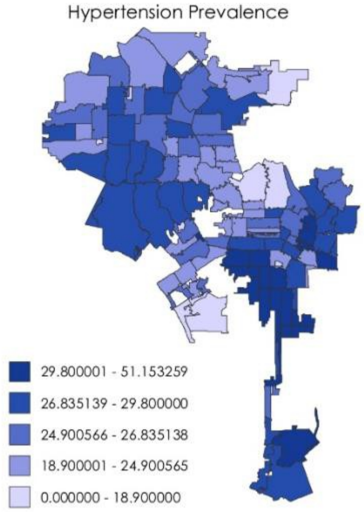
COPD Prevalence



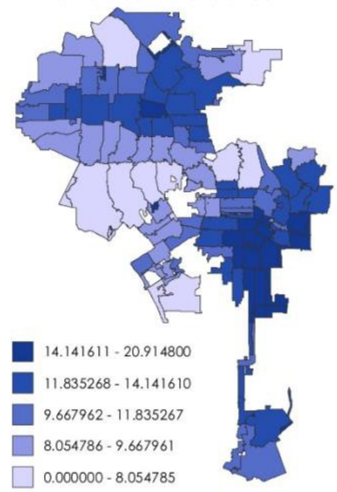
Cancer Prevalence



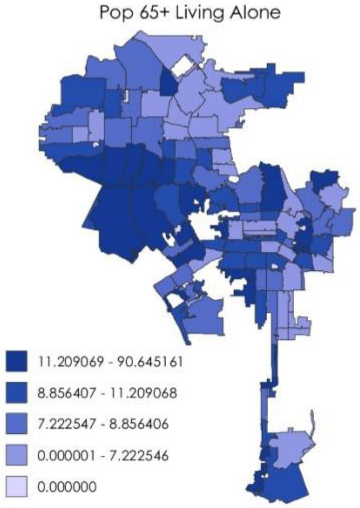
Hypertension Prevalence



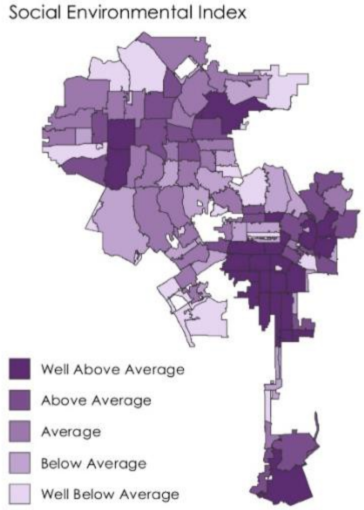
Mental Health Prevalence



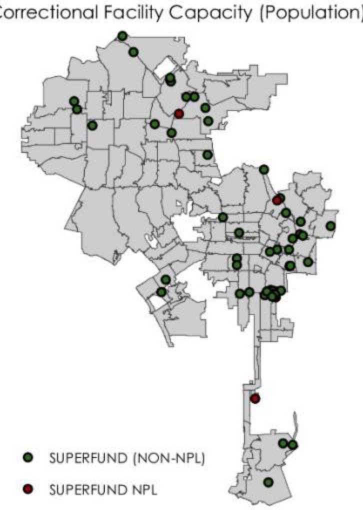
Pop 65+ Living Alone

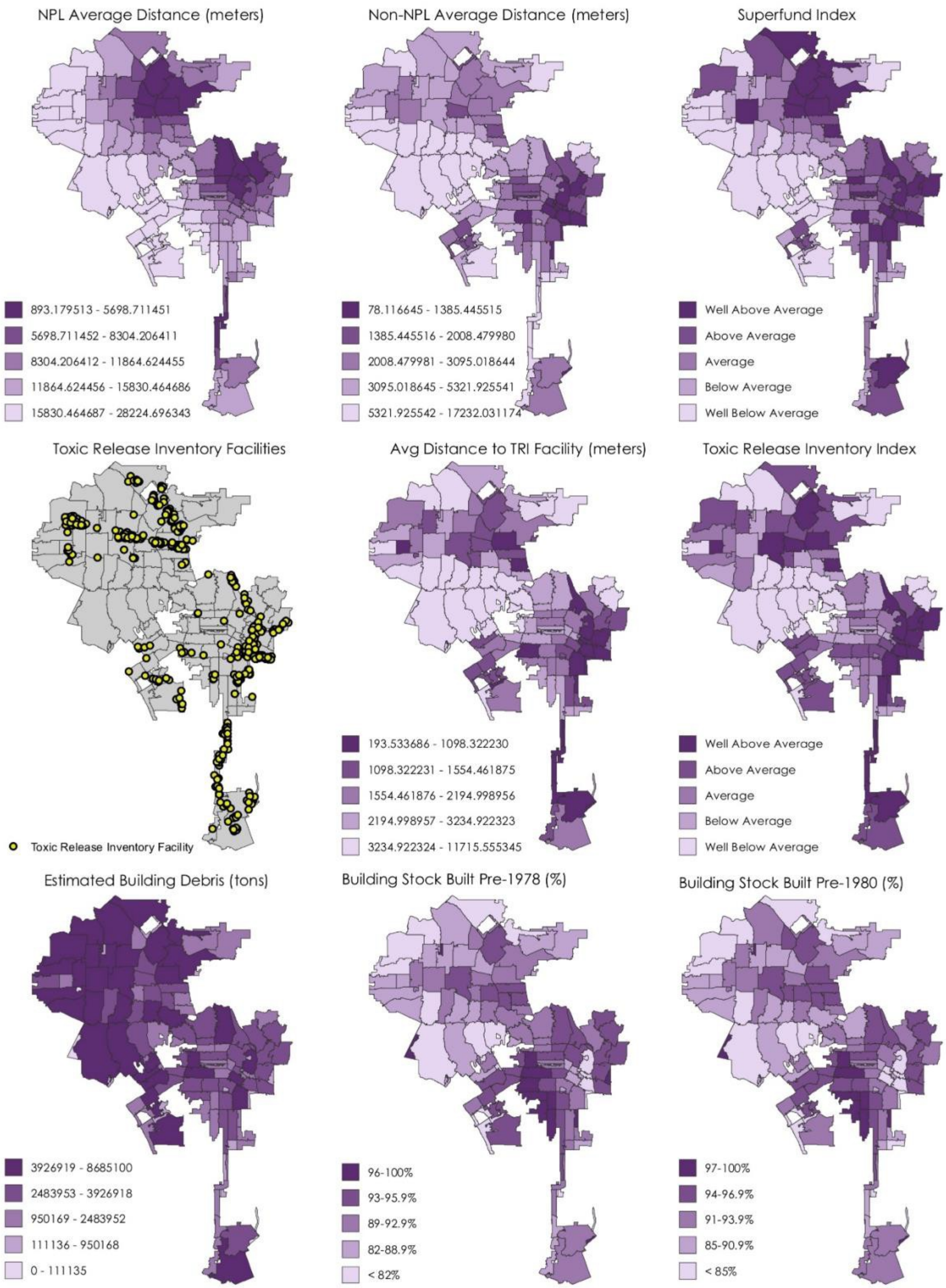


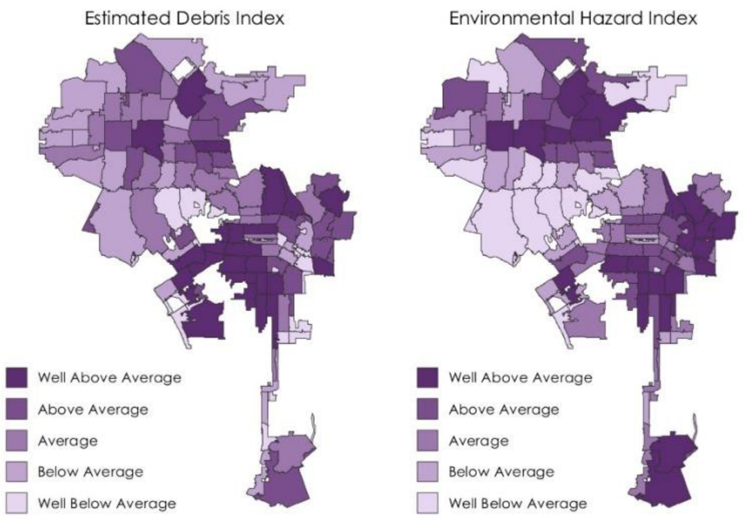
Social Environmental Index



Correctional Facility Capacity (Population)




NPL Average Distance (meters)
893.179513 - 5698.711451
5698.711452 - 8304.206411
8304.206412 - 11864.624455
11864.624456 - 15830.464686
15830.464687 - 28224.696343
Non-NPL Average Distance (meters)
78.116645 - 1385.445515
1385.445516 - 2008.479980
2008.479981 - 3095.018644
3095.018645 - 5321.925541
5321.925542 - 17232.031174
Superfund Index
Well Above Average
Above Average
Average
Below Average
Well Below Average
Toxic Release Inventory Facilities
Toxic Release Inventory Facility
Avg Distance to TRI Facility (meters)
193.533686 - 1098.322230
1098.322231 - 1554.461875
1554.461876 - 2194.998956
2194.998957 - 3234.922323
3234.922324 - 11715.555345
Toxic Release Inventory Index
Well Above Average
Above Average
Average
Below Average
Well Below Average
Estimated Building Debris (tons)
3926919 - 8685100
2483953 - 3926918
950169 - 2483952
111136 - 950168
0 - 111135
Building Stock Built Pre-1978 (%)
96-100%
93-95.9%
89-92.9%
82-88.9%
< 82%
Building Stock Built Pre-1980 (%)
97-100%
94-96.9%
91-93.9%
85-90.9%
< 85%


Estimated Debris Index
Well Above Average
Above Average
Average
Below Average
Well Below Average
Environmental Hazard Index
Well Above Average
Above Average
Average
Below Average
Well Below Average