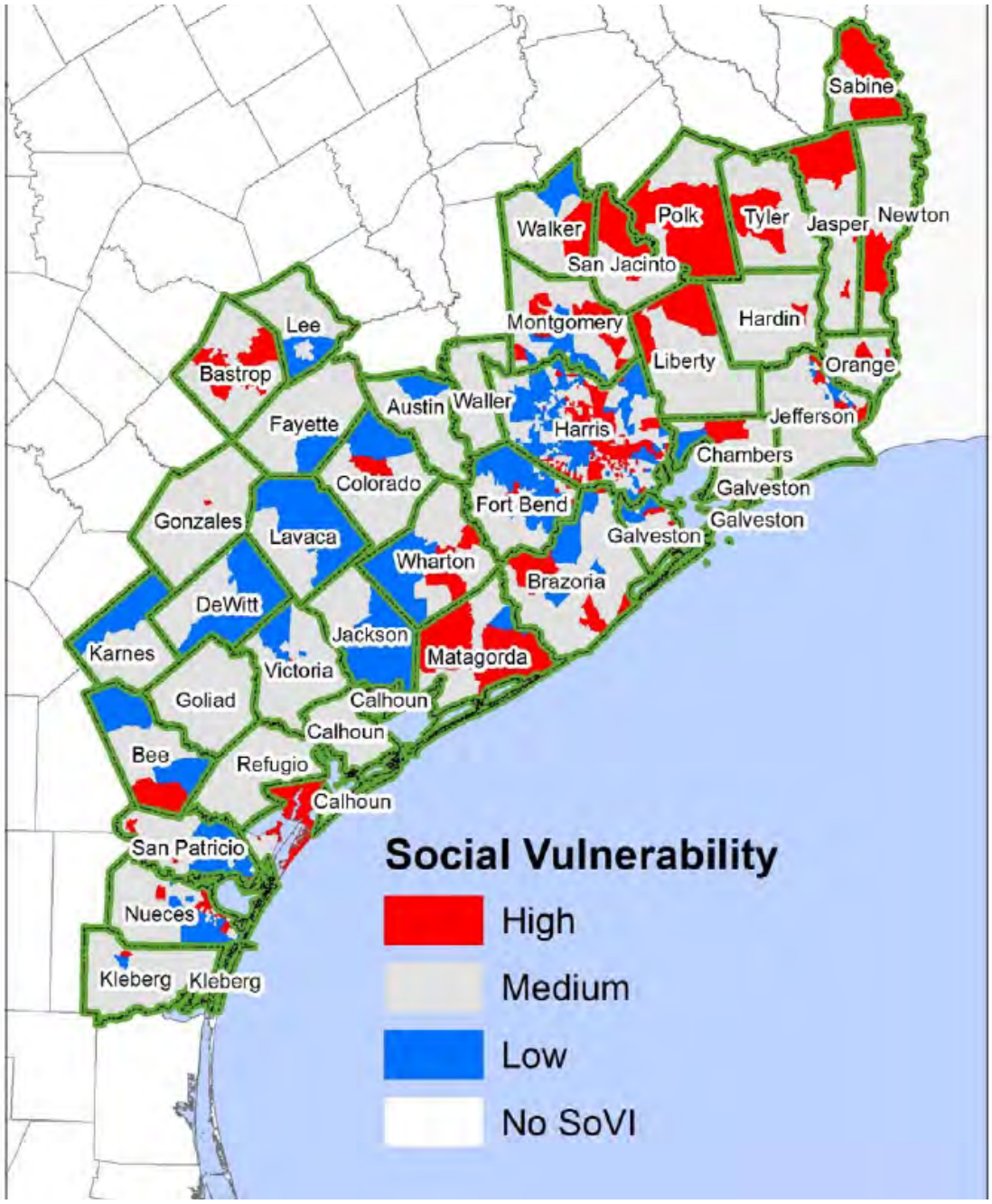
Social Vulnerability and Hazard Analysis for Hurricane Harvey

Background and Methods



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Social Vulnerability

The concept of vulnerability, or the potential for harm, first introduced into the hazards and disasters literature in the 1970s, provided a means for understanding the interactions between social and ecological systems. It also provided understanding on how such interactions give rise to hazards and disasters (O'Keefe et al., 1976). Vulnerability explains the differential impacts of shocks or stressors to natural systems and the ability of those systems to absorb and withstand impacts (biophysical vulnerability). A companion construct, social vulnerability, provides the societal context within which such stressors operate and highlights the uneven capacity for preparedness, response, recovery, and adaptation to environmental threats in and across social systems. Conceptually, vulnerability is understood to be inherent in the social system, independent of the hazard (Cutter et al., 2000 and 2003). However, to fully understand and characterize the hazards of places, measures of the physical characteristics of hazards and the environment (i.e., hazard exposure) must be combined with those social, economic, and demographic characteristics that influence a community's ability to prepare for, respond to, cope with, recover from, and ultimately adapt to environmental hazards (Cutter et al., 2000). Vulnerability is widely used in the hazards, disasters, and human dimensions of global change literature to describe the differential impacts of environmental threats on people and the places where they live and work (Pelling, 2003; Wisner et al., 2004; Adger, 2006; Birkmann, 2006; Eakin and Luers, 2006; Fussell, 2007; Polsky et al., 2007).

The Social Vulnerability Index (SoVI) is a quantitative measure of social vulnerability to environmental hazards. Originally developed in 2003 and applied to counties in the United States, SoVI provides a comparative metric that facilitates the geographic examination of differences in levels of social vulnerability across states and regions (Cutter et al., 2003). Based on extensive research literature focused on post-disaster response and recovery that now spans nearly a half century (NRC, 2006), SoVI includes those population characteristics known to influence the ability of social groups and communities to prepare for, respond to, and recover from disasters, especially coastal disasters (Heinz Center, 2002). The index synthesizes these socioeconomic variables into multiple dimensions, and sums the component values to produce the overall score for the particular spatial unit (e.g., county, census tract) of interest[1]. Conceptually, SoVI relates well to indices of social well-being, but its focus is on environmental hazards and the capacity of social groups to prepare for, respond to, and recover from disasters. For example, socioeconomic status (wealth or poverty) affects the ability of a community to absorb losses. Wealth enables communities to withstand the impact of losses more readily than those communities in poverty because of their access to capital, insurance, and so forth. Age is another characteristic that influences vulnerability, and this is normally recognized at the two extremes of the age continuum—children and older adults. These age cohorts need special care, are often more susceptible to harm, and may have mobility constraints, all of which influence the ability to get out of harm's way. Special needs populations (e.g., nursing home residents, infirmed) are another example of a highly vulnerable population as they are often difficult to identify. Gender, race, and ethnicity often impose language and cultural barriers, affect access to post-disaster recovery funding, and often constrain employment opportunities and access to education. Finally, housing type and tenure (e.g., manufactured housing and renters) influence vulnerability. Manufactured housing is not as reliable as a sheltering option in high wind environments, for example. Renters are more

[1] See methods section for more information on variables and construction of SoVI

vulnerable than homeowners are because they live in temporary quarters, often do not have renters insurance to cover the loss of their personal property, and lack strong social ties to the community.

The project represents an improvement in the SoVI, which now only examines those specific social and demographic correlates of vulnerability, and is more reflective of social well-being. In the original formulation (Cutter et al., 2003), there were ten additional variables that measured aspects of the built environment (e.g., housing age) and county economic activity. We have now separated these into a companion Built Environment Index (BEVI), which is not included in this analysis. This new formulation of SoVI provides a more robust snapshot of those social group characteristics that are associated with vulnerability and known, based on the case study and empirical research literature, to either enhance or retard hazard preparedness, response, recovery, and mitigation/adaptation.

Methods

The original SoVI formulation used 42 variables (derived from the United States Census) for each county in the nation. The original computation included social and demographic characteristics as well as some measures of county economic productivity and growth. Because one could argue that economic productivity was more reflective of built environment indicators (e.g., the density of manufacturing establishments) rather than social indicators, these variables were deleted in this analysis. As a result, SoVI now reflects those characteristics of social groups that influence their differential capacity to prepare for and respond to environmental threats.

Twenty-seven variables were used in the SoVI-Harvey2015 computation (Table 1), based on the research literature described above. To facilitate comparisons across counties, all data were from the United States Census Decennial product (2010) and United States Census rolling 5-year American Community Survey (ACS) product (2011-2015). The Census 2010 data represent true counts of the population and their characteristics.

Table 1: Known correlates of social vulnerability and variables used to compute SoVI-Harvey2015.*

Population Characteristic and Specific Variables	**Influence on Social Vulnerability**
Race & ethnicity % African American % Native American % Asian or Pacific Islander % Hispanic	Imposes language and cultural barriers for disaster preparedness and response; affects access to pre and post-disaster resources; minority group tendency to occupy high hazard areas; non-white and non-Anglo populations are viewed as more vulnerable.
Socioeconomic Status Per capita income % households earning more than $200,000 % poverty	Affects community ability to absorb losses; wealth enables communities to recover more quickly using insurance and personal resources; poverty makes communities less able to respond and recover quickly.

Gender % females in labor force % female population % female headed household, no spouse present	Women often have a more difficult time coping after disasters than men due to employment sector (personal services), lower wages, and family care responsibilities.
Age Age depended populations (% population under 5 years old and % population over 65) Median age	Age extremes increase vulnerability; parents must care for children when day care facilities are not available; older adults may have mobility or health problems.
Renters % renters Median Gross Rent	Renters are viewed as transient populations with limited ties to the community; they often lack shelter options when lodging becomes uninhabitable after disasters or too costly; lack insurance; often lack savings.
Residential property Median value of owner occupied housing % housing units that are mobile homes % unoccupied housing units	The value, quality, and density of residential construction affect disaster losses and recovery; expensive coastal homes are costly to replace; mobile homes are easily damaged.
Occupation % employed in farming, fishing, forestry % employed in service occupations	Some occupations, especially those involving resource extraction (e.g.,fishing, farming), can be affected by disasters; service sector jobs suffer as disposable income declines; infrastructure employment (e.g., transportation, communications, utilities) is subject to temporary disruptions post-disaster.
Family Structure Average number of people per household % children living in 2 parent families	Families with large numbers of dependents or single parent households may be more vulnerable because of the need to rely on paid caregivers.
Employment % civilian labor force unemployed	Communities with high numbers of unemployed workers (pre-disaster) are viewed as more vulnerable. Because jobs are already difficult to obtain, this slows the recovery post-disaster.
Education % population over 25 with no high school diploma	Limited educational levels influence ability to understand warning information and likely disaster impacts; access to post recovery resources.
Population Growth	New immigrant populations lack language skills and are unfamiliar with state and federal bureaucracies in how to obtain

% ESL (poorly or not at all)	disaster relief; may not be permanent or legal residents; unfamiliar with range of hazards in area.
Social Dependency and Special Needs Populations % collecting social security benefits Per capita residents in nursing homes % no automobile	Residents totally dependent on social services for survival are often economically marginalized and thus more vulnerable; special needs populations (infirmed) require more time for evacuation and recovery is often difficult.

*Source: Heinz Center, 2002; Cutter et al., 2003.

The 27 variables were standardized and input into a principal components analysis (PCA) to reduce the number of variables into a smaller set of multi-dimensional attributes or components. Adjustments to the component's directionality were made to ensure that positive values were associated with increasing vulnerability, and negative values associated with decreasing vulnerability. If a factor included negative and positive values that both influenced vulnerability (such as older adults and the young), then the absolute value was used. Once the directionality was established, the components were added together to produce the final SoVI score for 39 Texas counties declared as presidential disaster areas and eligible for individual assistance disaster area Florida (SoVI-Harvey2015).

Seven distinct components explain 73.58% of the variance within the data for the SoVI-Harvey2015 (Table 2). This amount of explained variance falls in line with the results from most of the SoVI models ever implemented by the Hazards and Vulnerability Research Institute. Generally speaking, the more variables within the model, the more variance explained. However, it is important to also remove co-linearity in the dataset by a reduction of input variables. A by-product of this reduction is a lower variance explained. These components include race (black) and social status, wealth (per capita income, percent rich, median house value), ethnicity (Hispanic populations), age (older adults), gender (females and female labor force participation), unemployment, and race (Native American). These components and the level of explained variance are consistent with other SoVI studies for different regions and for the United States as a whole. There is considerable sensitivity testing of the SoVI metric to monitor its robustness at different spatial scales and in different places (Schmidtlein et al., 2008), and in different application domains (see http://sovius.org).

Table 2: Social Vulnerability Index-Harvey in Texas (SoVI-Harvey2015)[2].

Component	*Cardinality*	*Name*	*% Variance Explained*	*Dominant Variables*	*Component Loading*
1	+	Race (Black) and Social Status	15.20	QBLACK	0.7029
				QNOAUTO	0.8128
				QPOVTY	0.6958
				QRENTER	0.6254
				QFHH	0.6088
				QSERV	0.5442
				QFAM	-0.6675
2	-	Wealth	15.10	PERCAP	0.8526
				MHSEVAL	0.8831
				QRICH200K	0.8828
				MDGRENT	0.6090
3	+	Ethnicity (Hispanic)	13.79	QESL	0.8635
				QHISP	0.8553
				QED12LES	0.8192
				PPUNIT	0.6998
				QPOVTY	0.5074
4	+	Age (Old)	12.30	QSSBEN	0.8587
				QAGEDEP	0.7785
				MEDAGE	0.6672
				QUNOCCHU	0.6364
5	+	Gender (Female)	8.46	QFEMALE	0.8736
				QFEMLBR	0.8475
6	+	Unemployment	4.89	QCVLUN	0.5098
				QNRRES	-0.5320
7	-	Race (Native American)	3.83	QNATAM	-0.8957
		Cumulative Variance Explained	**73.58**		

State Summary

The social vulnerability scores, ranging from 20.18 indicating the most vulnerable tract (in Polk County) to -11.15, the least vulnerable tract (in Victoria County), were mapped using a three-class standard deviation method. The standard deviations preserve the underlying distribution of the data (mean of zero and one-half standard deviation on either side) (Figure 1). The moderate category represents the mean; the elevated category is greater than one-half standard deviation above the mean; and the low category is more than one-half standard deviation below the mean. This method permits the best balance between interpretation (three classes) and the identification and visualization of the extremes (high and low vulnerability that are of the most interest).

[2] To learn more about SoVI or the variable naming conventions visit - http://webra.cas.sc.edu/hvri/products/sovi_details_2006.aspx

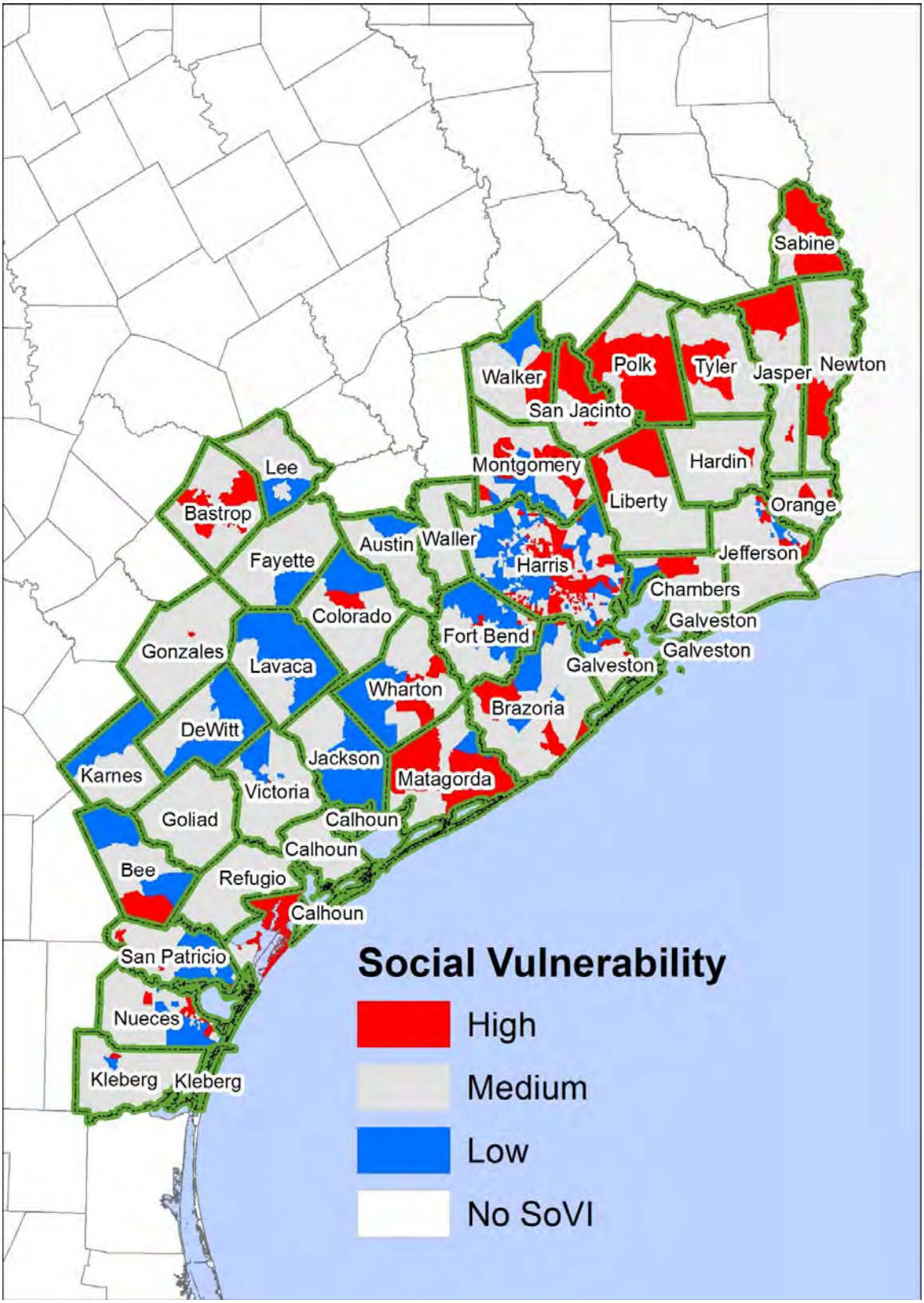

Figure 1: SoVI-Harvey2015 - tract level social vulnerability for the presidential declared individual assistance counties of Texas.

Overall, social vulnerability at the tract level for the state is driven by the place specific combination of underlying socioeconomic and demographic conditions present at the local level. These baseline conditions are teased out and merged into “components” through the factor analytic process. Mapping of each component provides a different view of the drivers of vulnerability across the state and may be useful for planning, exercise design, and the allocation of goods and services within the context of emergency management (Figure 1).

Table 4 provides a population count by county for comparative purposes. Here, one can easily see that Harris County (Figure 4) has the highest populations living in socially vulnerable areas, followed by Nueces County.

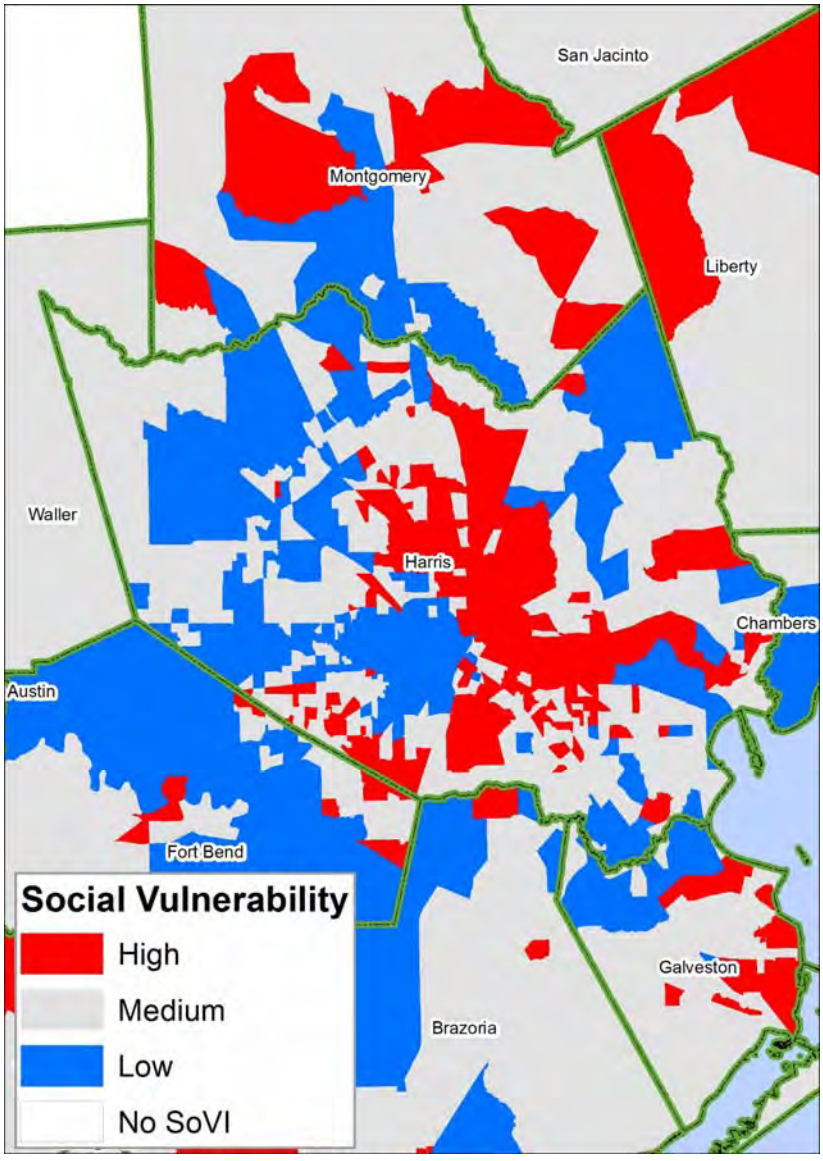

Figure 4: SoVI-Harvey2015 - tract level social vulnerability for the Harris County, Texas.

Using these tables in combination with the map above is the only accurate way to understand where clusters of vulnerability are occurring. Identification of and discussion about these areas of higher vulnerability can be found below.

Table 4: Census tract summary of population by SoVI class by county (SoVI-Harvey2015).

	Social Vulnerability Rank				Social Vulnerability Rank		
County Name	**High**	**Medium**	**Low**	**County Name**	**High**	**Medium**	**Low**
Aransas	6,731	17,561		Kleberg	5,369	12,636	14,024
Austin		24,150	4,736	Lavaca		9,494	10,055
Bastrop	24,626	52,322		Lee		13,759	2,905
Bee	9,794	12,627	10,238	Liberty	18,838	58,648	
Brazoria	42,876	175,166	113,699	Matagorda	7,845	27,466	1,287
Calhoun		15,946	5,720	Montgomery	92,150	212,772	197,664
Chambers	2,426	17,733	17,092	Newton	2,103	12,128	
Colorado	3,774	11,645	5,338	Nueces	138,496	136,696	76,868
DeWitt		8,549	11,991	Orange	23,577	57,090	2,550
Fayette		19,721	5,128	Polk	30,115	15,998	
Fort Bend	87,796	159,331	411,204	Refugio		7,277	
Galveston	83,522	126,052	98,589	Sabine	7,158	3,282	
Goliad		7,410		San Jacinto	9,507	17,516	
Gonzales	5,675	14,497		San Patricio	16,748	31,383	17,939
Hardin	4,472	50,903		Tyler	8,065	10,840	2,557
Harris	1,100,932	1,892,531	1,362,899	Victoria	14,125	61,297	14,677
Jackson		3,887	10,599	Walker	17,803	44,537	6,990
Jasper	17,320	18,448		Waller		45,847	
Jefferson	79,885	130,374	42,613	Warton	6,818	25,054	9,392
Karnes		12,417	2,462	**Area Total**	**1,868,546**	**3,574,990**	**2,459,216**

The pattern of elevated social vulnerability across the Harvey IA declared counties (Figure 1) is concentrated mainly in Harris County (figure 4), where 14 of the top 25 most vulnerable census tracts are found (table 5). While vulnerability is a product of a diverse set of drivers particular to each enumeration unit a details look into the most vulnerable census tracts show that in most cases vulnerability is driven up by component 1 - Race (Black), Ethnicity (Hispanic) and social status. Of particular interest is the difference in overall vulnerability and its constituent parts between these areas of extreme vulnerability.

Table 5: Driving forces of the most vulnerable tracts in SoVI-Harvey2015.

County	Tract	Total Population	Comp 1 - Race (Black) and social status	Comp 2 - Wealth	Comp 3 - Ethnicity (Hispanic)	Comp 4 - Age (Old)	Comp 5 - Gender (Female)	Comp 6 - Unemployment	Comp 8 - Race (Native American)	SoVI Score	Congressional Representative
Polk	48373210500	4,661	0.14	-0.92	-0.65	1.97	-0.64	2.04	-16.39	20.18	Brian Babin
Harris	48201331400	2,303	6.65	0.20	-0.57	1.92	1.81	1.52	-4.75	15.88	Al Green
Harris	48201222900	9,040	-0.43	-0.35	2.30	-0.12	-0.24	1.85	-5.65	9.36	Gene Green
Harris	48201552103	3,214	-0.72	-0.39	0.04	-0.36	0.22	1.53	-7.71	8.81	John Culberson
Galveston	48167723501	1,041	-0.96	-0.68	-0.62	0.88	0.20	1.85	-6.13	8.17	Randy Weber
Harris	48201555100	9,081	-0.75	-0.31	-0.44	-0.65	0.78	1.82	-6.74	7.80	Kevin Brady
Galveston	48167723700	2,036	1.44	-0.78	-0.66	0.75	1.23	0.38	-3.27	7.19	Randy Weber
Harris	48201332400	3,896	1.54	-0.45	-0.73	1.07	1.20	2.31	-1.18	7.02	Al Green
Nueces	48355002001	4,118	0.51	-0.72	0.74	0.29	0.16	0.17	-4.36	6.96	Blake Farenthold
Harris	48201321500	2,977	0.88	-0.31	2.10	-0.35	-0.20	-0.16	-3.71	6.30	Gene Green
Harris	48201251300	7,844	-0.88	0.31	-0.72	0.02	-0.22	1.54	-6.74	6.17	Ted Poe
Harris	48201313800	4,490	3.50	-0.35	-0.99	0.29	1.41	0.90	-0.57	6.03	Sheila Jackson
Nueces	48355001100	1,881	3.06	-0.07	1.07	0.95	0.65	-0.37	-0.48	5.91	Blake Farenthold
Harris	48201221100	3,717	-0.43	-0.18	2.54	0.12	-1.11	1.42	-3.17	5.87	Gene Green
Harris	48201332000	5,450	3.15	-0.14	-0.26	1.39	0.78	1.52	1.01	5.71	Sheila Jackson
Jefferson	48245006700	2,910	-0.28	-0.54	0.76	-0.05	-0.87	1.37	-4.22	5.70	Randy Weber
Jefferson	48245000900	2,030	3.43	-0.66	-0.95	0.93	0.73	1.61	0.71	5.70	Randy Weber
Harris	48201211200	2,553	2.39	-0.45	-0.06	1.22	1.18	1.01	0.51	5.67	Sheila Jackson
Harris	48201553300	5,844	1.61	-1.07	-1.11	-1.31	1.47	-1.00	-4.89	5.61	Sheila Jackson
Jefferson	48245000103	3,171	3.66	-0.69	-1.26	0.06	1.99	0.93	0.59	5.50	Randy Weber
Harris	48201220800	2,787	2.85	0.23	1.01	0.84	-0.68	1.37	-0.19	5.35	Sheila Jackson
Harris	48201322800	6,104	-0.77	-0.37	1.74	-0.10	-0.60	1.13	-3.58	5.35	Gene Green
Jefferson	48245005900	1,561	4.16	-0.39	-1.59	0.51	1.45	1.09	0.69	5.31	Randy Weber
Montgomery	48339692500	8,978	-0.67	-0.99	0.40	0.82	-0.30	1.24	-2.79	5.28	Kevin Brady
Nueces	48355001500	4,235	2.51	-0.24	1.17	1.32	0.14	-0.34	-0.01	5.05	Blake Farenthold

Vulnerability Driver Vulnerability Detractor

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