Social Vulnerability eXplorer (SV-X)

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ABSTRACT

The Social Vulnerability eXplorer (SV-X) system is being developed by the Army Corps of Engineers to aid understanding and communication of spatial distributions of vulnerable populations in hazard zones. SV-X's interactive maps, tabular displays, and exportable datasets provide valuable insights into mitigations, preparedness, and response measures needed for areas of high social vulnerability to environmental hazard including floods, coastal storm surges, impacts, and erosion. This paper provides background on social vulnerability research supporting the development of the SV-X, and introduces the SV-X's interactive web-based visualization and analysis tool for examining the social vulnerabilities of populations at risk from environmental hazard. The results are intended to help civil works project planners include social factors in their analysis of alternative risk reduction measures, and comparisons of "with-project" and "without-project" conditions. Disaster recovery planners may find utility in the SV-X's ability to assess sizes and social vulnerability characteristics of populations in disaster impact zones.

BACKGROUND

Measurement of human vulnerability to a hazard is based in part on the physical nature and proximity to the threat. It also results from social factors (Cutter et al. 2000), that interfere with people's ability to move from harm's way and recover once impacted by a traumatic event. In a landmark study of social vulnerability of groups most directly impacted by a hurricane, Professor Patrick Sharkey of New York University's Department of Sociology (Sharkey 2007) took an empirical look at victims of 2005's hurricane Katrina in New Orleans. He found "the impact of the storm was felt most acutely by the elderly population in New Orleans and by Blacks, who were much more likely to die than would be expected given their presence in the population."

Of the 555 hurricane victims studied, "...67% were at least 65 years old. By contrast, only about 12% of New Orleans' population was 65 or older". The elderly population's death rate was more than 15 times higher than the death rate of the nonelderly population (i.e. < 65 years of age.) "The racial composition of the nonelderly victims", Prof. Sharkey pointed out, "is significantly different from what would be expected given the racial composition of the nonelderly population of New Orleans." That is, "...the death rate for Blacks is almost double that for Whites (5 per 10,000 vs. 2.7 per 10,000). The same pattern emerges in the elderly population", the sociologist observed, "the death rate for elderly Blacks is about 74 per 10,000 compared to the rate of 52 per 10,000 elderly White residents."

Sharkey's case study demonstrated statistically significant relationships between social

characteristics of people and groups, such as race and age, and their risk of dying from flood hazard exposure. This finding is consistent with similar social science research conducted over the last fifty years which points to common social factors that increase and decrease the impact a disaster has on local populations (Dunning and Durden, 2009.) "While all people living in flood hazard areas are affected," Dunning and Durden (2011) instruct, "the social impacts of hazard exposure often fall disproportionately on the most vulnerable people in society - the poor, minorities, children, the elderly, and the disabled." Wealthier communities, for example, with more resources, insurance, and property to lose can absorb losses and recover quicker than low-income communities often located in higher-risk locations and substandard housing, with scarce resources for responding to and recovering from disaster.

The term, social vulnerability "refers to the capacity for being damaged or negatively affected by hazards or impacts" (Dunning and Durden 2009.) The related term resiliency describes characteristics influencing capacity of individuals or groups to anticipate, cope with, resist, or recover from the impact of a hazard. Social vulnerability analysis is a form of geographic profiling which examines vulnerability and resiliency of populated places to environmental hazard. It is conducted by overlaying the spatial distribution of population characteristics reported by the U.S. Census Bureau with hazard areas (Cutter et al. 2008), and tallying populations and subgroups at risk by their relative vulnerabilities. Table 1 illustrates a social vulnerability profile of an area at risk from a 100-year flood (i.e. 1% chance of recurring each year) and a larger 500-year recurring flood (i.e. 0.2% chance of recurring each) without flood protection.

Table 1. Population at risk in .2% chance floodplain and 1% chance floodplain without flood protection project, and break-down by vulnerable groups.

Existing Risk	0.2% Chance	1% Chance
Population at risk for flooding:	89,060	55,663
Disabled:	*16,478*	*10,299*
Elderly:	*12,395*	*7,747*
Poor:	*11,200*	*7,000*
Very young:	*6,520*	*4,075*

As can be seen in Table 1, the disabled comprise over 18% of the population in both floodplains. Similarly, those 65 years of age and older comprise over 18% of the population living in the 500-year (0.2% Chance) floodplain, and 14% of the population living in the 100-year (1% Chance) floodplain. Table 2 provides vulnerability profiles of three alternative plans for a possible flood protection project for mitigating the existing risk shown in Table 1. The social vulnerability profiles in the figure illustrate that plans A, B, and C provide different levels of hazard protection for 1% flood events, but not for 0.2% flood events.

To simplify the task of simultaneously assessing multiple profile variables to examine social vulnerability of a place, Cutter et al. (Cutter et al. 2003) developed the Social Vulnerability Index (SoVI.) It is calculated from U.S. Census Bureau demographic, socioeconomic, and housing unit data, and represents social vulnerability as a single numeric value provided to each census unit (i.e. county, tract, or block group). The SoVI value for each census unit is a statistical measurement of its vulnerability in relationship to the average vulnerability of neighboring census units across a broader region, as expressed by a Z-score. Figure 1 illustrates that a census unit's SoVI Z-score can be zero (indicating the census unit has average or mean vulnerability), or

it can be positive or negative, indicating whether it is above or below the average vulnerability of the region, and by how many standard deviations. More information on constructing the SoVI can be found in Cutter et al. 2003, Dunning and Durden 2009, and Dunning and Durden 2011.

Table 2. Population at risk in 500 year floodplain (0.2% Chance floods) and 100 year floodplain (1% Chance floods), and break-down by vulnerable groups.

Residual Risk	Plan A	Plan B	Plan C
Population at risk for flooding			
0.2% Chance:	89,060	89,060	89,060
Disabled:	16,478	16,478	16,478
Elderly:	12,395	12,395	12,395
Poor:	11,200	11,200	11,200
Very young:	6,520	6,520	6,520
1% Chance:	5,010	0	16,699
Disabled:	1,030	0	5,150
Elderly:	775	0	3,874
Poor:	700	0	4,200
Very young:	408	0	1,223

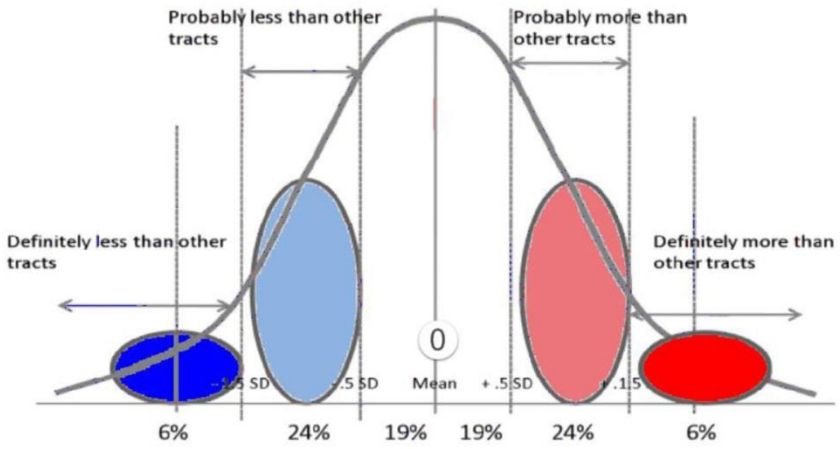


Figure 1. Using Z-scores to categorize social vulnerability.

SOCIAL VULNERABILITY EXPLORER (SV-X)

The Social Vulnerability eXplorer (SV-X) is a system intended to help planners of hazard impact protection mitigations and disaster recovery managers examine the population at risk and determine where concentrations of socially vulnerable populations are located. The SV-X system consists of three components:

1) SV-X Analysis tool
2) Social vulnerability index map
3) SoVI Data Development tool

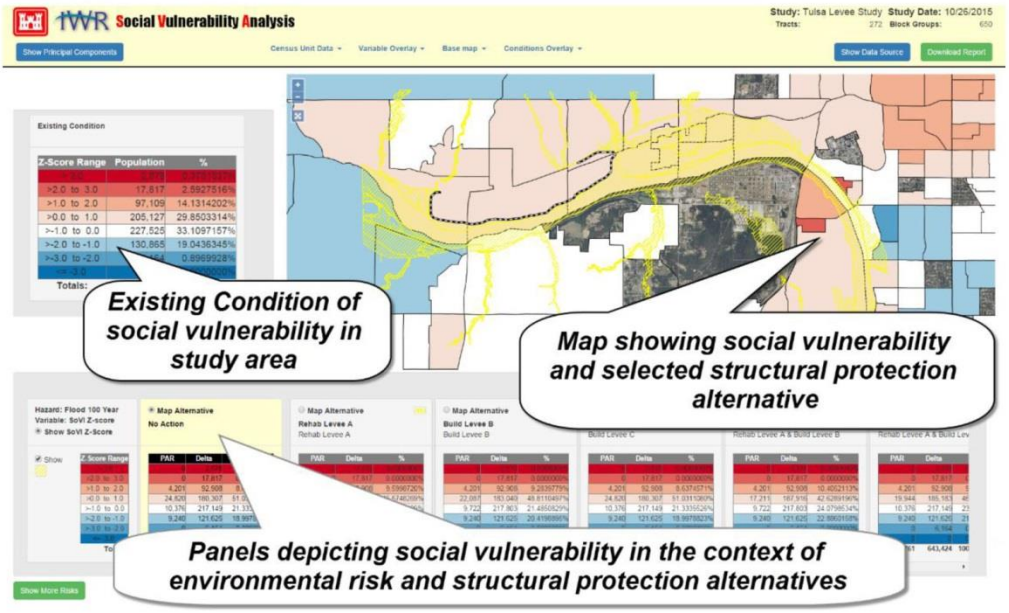


Figure 2. SV-X Analysis tool's screen enables interactive examination of hazard areas and social vulnerability of populations at risk in a study area.

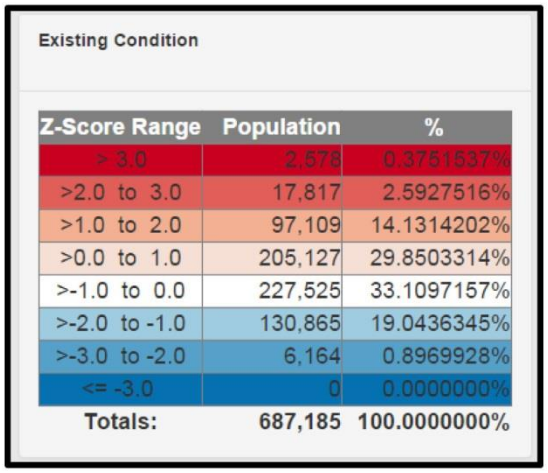
SV-X Analysis Tool

The SV-X Analysis tool, depicted in Figure 4, is an interactive web-based analysis application for examining hazard areas and the vulnerability of populations at risk in a study area. The Analysis tool's user interface (Figure 2) contains an "Existing Condition" table detailing the social vulnerability of the population in the study area, a hazard and hazard protection map, and one or more rows of protection alternatives.

Figure 3 illustrates the use of SoVI Z-score ranges in the Existing Condition table to group and order subpopulations within study area by social vulnerability. Social vulnerability groups are ranked from most vulnerable at the top of the table to least vulnerable (i.e. most resilient) at the bottom of the table. The four positive SoVI Z-score ranges in the top half of table identify groups of people more socially vulnerable than that of the average population, with correspondingly deeper shades of red. Moving towards the bottom, the four groups in the lower half of the table identify groups with decreasing social vulnerability and increasing resilience, with white and correspondingly deeper shades of blue.

The map to the right of the Existing Condition table (Figure 2) depicts the impact area resulting from a hazard protection alternative superimposed on the spatial distribution of social vulnerability within the study area. Below the map, a row of panels illustrate hazard protection alternatives and social vulnerability of the population at risk. The first panel describes the social vulnerability of the population at risk without implementation of a hazard mitigation project. This is called the "No-Action" alternative in the Analysis tool and is illustrated in Figure 4. In a disaster response management context, the panel for the No-Action alternative displays the social vulnerability distribution of the population in the impact area. In planning contexts, the No-Action alternative reveals the social vulnerability distribution of the population at risk without a future project to protect them. The subsequent panels to the right of No-Action represent the alternative configurations of protection measures the plan is considering. For example, Figure 4's panel "Rehab Levee A" on right of the No-Action alternative represents social vulnerability of

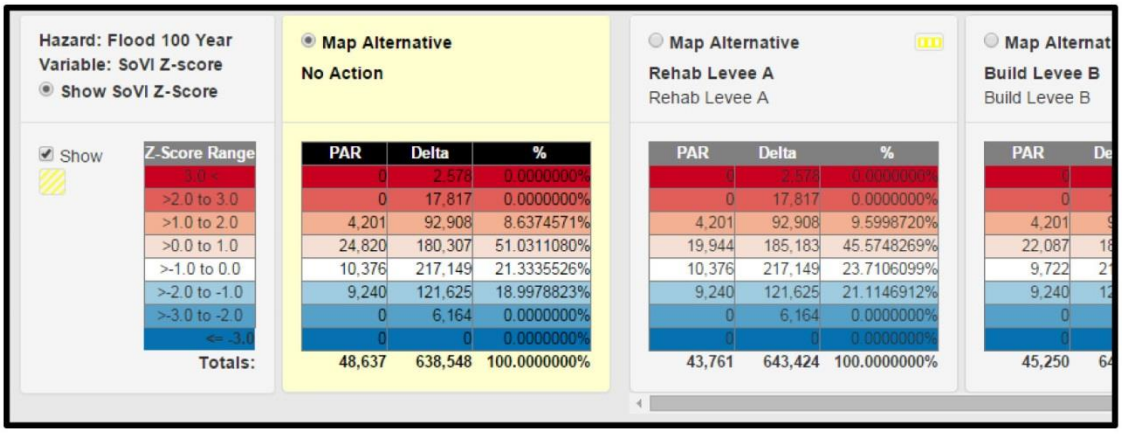
the residual population at risk, should the levee modification measures to rehabilitate Levee A be implemented.



Existing Condition

Z-Score Range	Population	%
> 3.0	2,578	0.3751537%
>2.0 to 3.0	17,817	2.5927516%
>1.0 to 2.0	97,109	14.1314202%
>0.0 to 1.0	205,127	29.8503314%
>-1.0 to 0.0	227,525	33.1097157%
>-2.0 to -1.0	130,865	19.0436345%
>-3.0 to -2.0	6,164	0.8969928%
<= -3.0	0	0.0000000%
Totals:	687,185	100.0000000%

Figure 3. Existing Condition table presents the study area's social vulnerability distribution of population in terms of Social Vulnerability Index (SoVI) values. [Note: Precision of % column assures values add up to 100%]



Hazard: Flood 100 Year
Variable: SoVI Z-score
Show SoVI Z-Score
Show

Z-Score Range
3.0 <
>2.0 to 3.0
>1.0 to 2.0
>0.0 to 1.0
>-1.0 to 0.0
>-2.0 to -1.0
>-3.0 to -2.0
<= -3.0
Totals:

Map Alternative
No Action

PAR	Delta	%
0	2,578	0.0000000%
0	17,817	0.0000000%
4,201	92,908	8.6374571%
24,820	180,307	51.0311080%
10,376	217,149	21.3335526%
9,240	121,625	18.9978823%
0	6,164	0.0000000%
0	0	0.0000000%
48,637	638,548	100.0000000%

Map Alternative
Rehab Levee A
Rehab Levee A

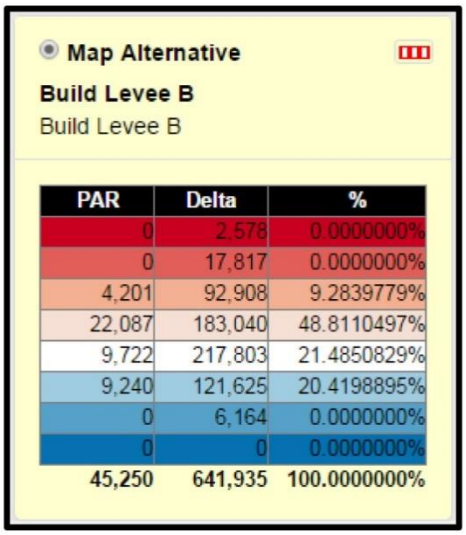
PAR	Delta	%
0	2,578	0.0000000%
0	17,817	0.0000000%
4,201	92,908	9.5998720%
19,944	185,183	45.5748269%
10,376	217,149	23.7106099%
9,240	121,625	21.1146912%
0	6,164	0.0000000%
0	0	0.0000000%
43,761	643,424	100.0000000%

Map Alternat
Build Levee B
Build Levee B

PAR	De
0	
0	
4,201	
22,087	18
9,722	21
9,240	12
0	
0	
45,250	64

Figure 4. Panels depict social vulnerabilities of residual populations at risk given alternative protection measures.

Referring to Figure 5, at the top of each alternative's panel is a radio button labeled 'Map Alternative' for selecting and displaying the spatial extent of the hazard and the location of the planned protection alternative in the map. Below the radio button is the name of the alternative and a table illustrating the social vulnerability of the population at risk given the protection measures (or lack of protection measures) for that alternative. The table consists of three columns. The first column displays the count of population at risk ('PAR') for each row's social vulnerability group. The second column, 'Delta', displays the difference between the social vulnerability group's population in the existing condition (i.e. without consideration of hazard) and the population at risk that falls within the hazard area. It indicates how many people in the study area of each social vulnerability grouping, are not affected by the hazard and thus not included in the population at risk. The third '%' column presents the percentage of the total population at risk that the social vulnerability group represents.



PAR	Delta	%
0	2,578	0.0000000%
0	17,817	0.0000000%
4,201	92,908	9.2839779%
22,087	183,040	48.8110497%
9,722	217,803	21.4850829%
9,240	121,625	20.4198895%
0	6,164	0.0000000%
0	0	0.0000000%
45,250	641,935	100.0000000%

Figure 5. An alternative's panel with social vulnerability of population at risk.

With the SV-X users can integrate, display, and analyze geospatial datasets representing multiple risk areas for the same hazard (e.g. 0.2% and 1% annual chance floodplains) or multiple hazards (e.g. floodplain and wind damage areas), with tract and block-group census unit SoVI datasets, for a study area. In Figure 6, top row panels for the study area display social vulnerability of population at risk in the 0.2% annual chance floodplain (i.e. 500-year flood). Bottom row panels display social vulnerability in the 1% floodplain (100-year flood). Social vulnerability summaries for the two risks in the case of the No-Action alternative are displayed in Figure 7.

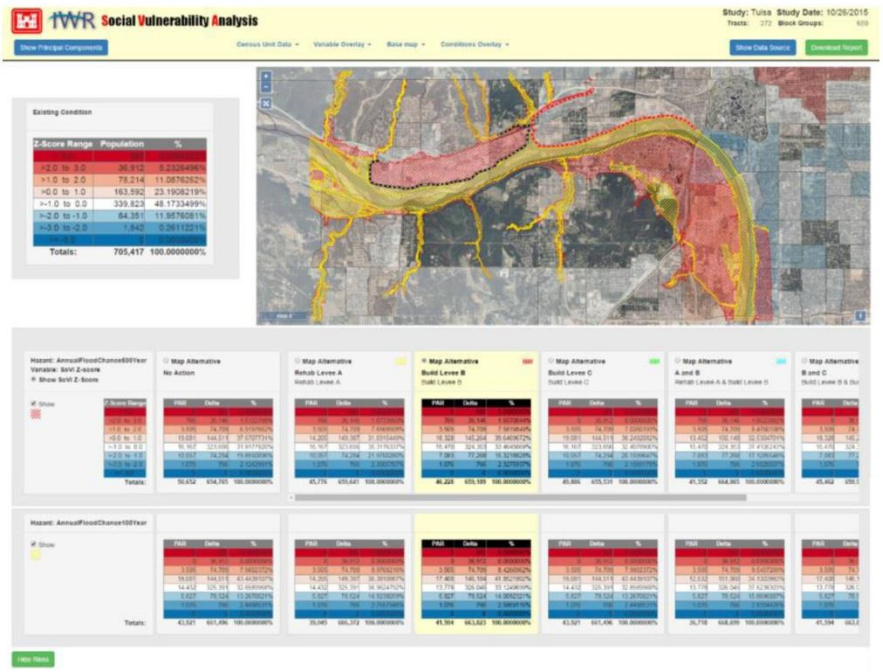


Figure 6. Selecting an alternative displays the locations of protection measures and hazard areas in the map.

SV-X users can drill down to the principal components the SoVI scores are based on to better understand factors influencing social vulnerability in the study area. Figure 8 juxtaposes the variation in population for SoVI with poverty and age to provide insight into the social vulnerability of the study area.

In addition to viewing data displayed within the screen of the SV-X Analysis tool, users can click a button an generate and download an Excel report containing the full range of social vulnerability data pertaining to the Existing Condition and the alternatives.

SV-X Index Map

The SV-X Index Map, depicted in Figure 9, is an interactive web page that enables prospective users to view, select among available SoVI study area datasets, and launch the SV-X Analysis web-based tool to work with a selected dataset. The web page provides a common place for project team members to share and browse SoVI datasets.

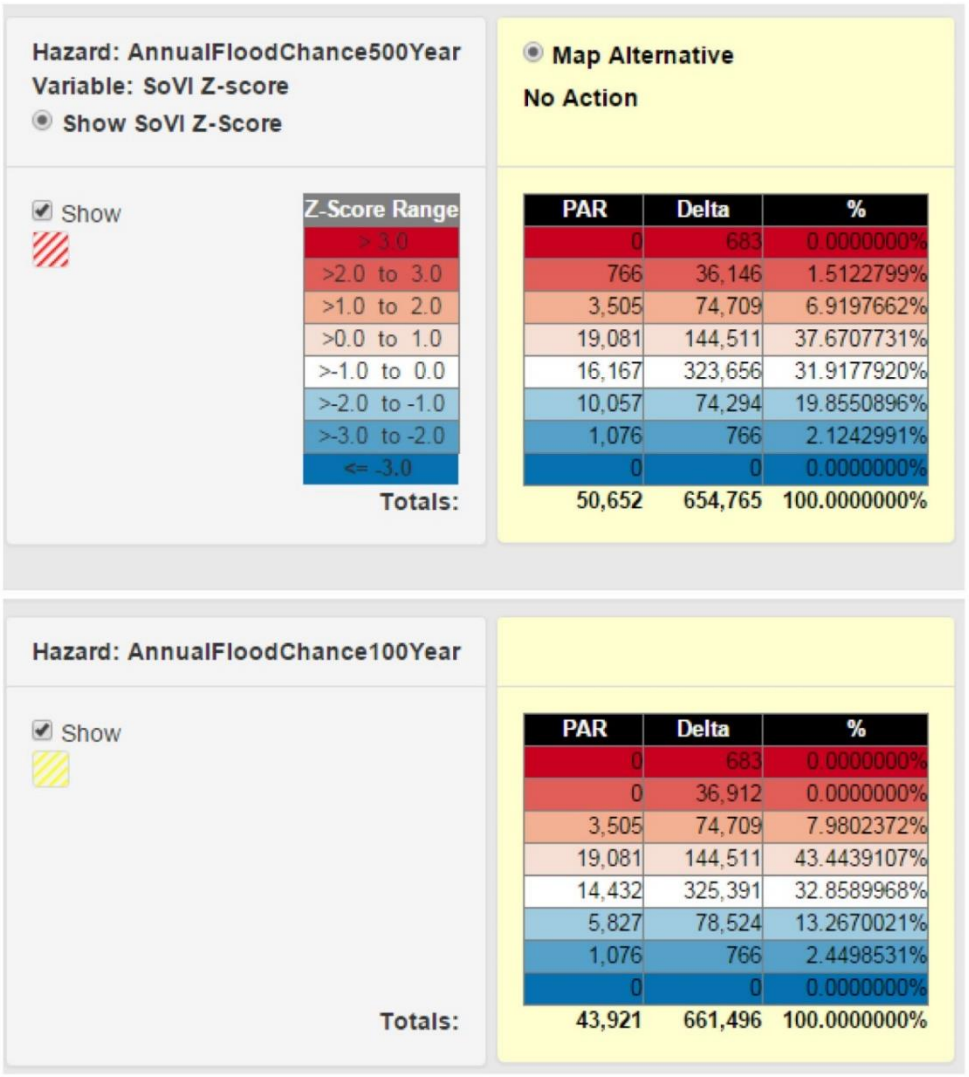


Figure 7. Social vulnerability summary for the 0.2% chance floodplain (i.e. 500-year flood) is show in the panel at the top of the figure, and for the 1% chance (i.e. 100-year flood) in the bottom panel.

Existing Condition			PC1 Poverty		PC4 Age	
Z-Score Range	Population	%	Population	%	Population	%
> 3.0	683	0.0968222%	12,148	1.7221020%	3,772	0.5347192%
>2.0 to 3.0	36,912	5.2326496%	23,000	3.2604828%	8,897	1.2612398%
>1.0 to 2.0	78,214	11.0876262%	47,633	6.7524599%	57,897	8.2074858%
>0.0 to 1.0	163,592	23.1908219%	156,418	22.1738348%	169,904	24.0856118%
>-1.0 to 0.0	339,823	48.1733499%	393,666	55.8061402%	339,262	48.0938225%
>-2.0 to -1.0	84,351	11.9576081%	72,552	10.2849804%	113,155	16.0408666%
>-3.0 to -2.0	1,842	0.2611221%	0	0.0000000%	12,530	1.7762543%
<= -3.0	0	0.0000000%	0	0.0000000%	0	0.0000000%
Totals:	705,417	100.0000000%	705,417	100.0000000%	705,417	100.0000000%

Figure 8. Juxtaposition of study area ("Existing Condition") population variance, expressed as SoVI Z-scores, with poverty and age Z-scores - two of six principal components this study area's SoVI is based on.

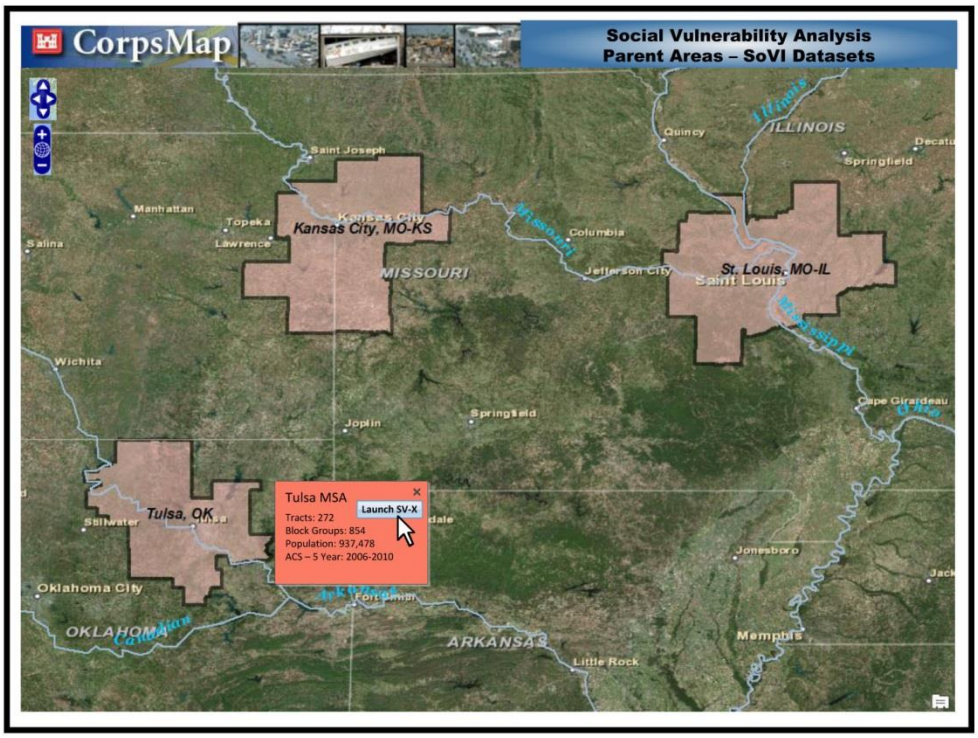


Figure 9. SV-X Index map enables users to view prior SoVI study area datasets and launch SV-X Analysis tool to work with one.

SV-X Data Development Tool

The SV-X Data Development tool is a Microsoft Windows-based desktop application for creating integrated SoVI hazard area datasets for conducting social vulnerability analyses. The data development tool works with standard U.S. Census Bureau Census and American Community Survey datasets and GIS-based hazard area datasets. The data development provides interactive wizards that guide the user through the steps of:

- Loading Census and hazard area datasets
- Producing SoVI scores and datasets
- Modifying prior SoVI hazard area datasets
- Exporting SoVI hazard area datasets for use in GIS and other applications
- Publishing SoVI hazard datasets and dataset updates to an enterprise Oracle database for use within the web-based SV-X Analysis tool

CONCLUSION

This paper has introduced the Social Vulnerability eXplorer (SV-X) system under development by the Army Corps of Engineers to aid understanding and communication of spatial distributions of vulnerable populations in hazard zones. SV-X's interactive maps, tabular displays, and exportable datasets provide valuable insights into mitigations, preparedness, and response measures needed for areas of high social vulnerability to environmental hazard including floods, coastal storm surges, impacts, and erosion. The geographic spatial analysis capabilities of the SV-X can help users jointly assess physical and social risk factors and identify vulnerable population areas for possible mitigation in the planning process. Social vulnerability analyses with the SV-X datasets and analysis tool can help answer questions, including:

- Who is at risk?
- Who is most vulnerable?
- What kinds of measures can best address the needs and interests of vulnerable groups?

By assisting in answering such questions, the SV-X is intended to help disaster recovery planners assess locations, sizes, and social vulnerability characteristics of populations in disaster impact zones. It is also designed to help civil works project planners include social factors in their analysis of alternative risk reduction measures and comparisons of "with-project" and "without-project" conditions.

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