USACE CAMPAIGN PLAN
Goal 2: Systems Approach

Social Vulnerability Analysis Methods for Corps Planning

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Abstract: Social effects have long been part of water resources planning in the United States. The experiences of Hurricanes Katrina, Rita, and Ike, as well as extensive flooding in the Upper Midwest, have again emphasized to the Nation the reality and significance of the social impacts of floods. One of the lessons of Katrina and Rita has been that the effects on socially vulnerable populations have been woefully overlooked and underestimated. While all people living in flood hazard areas are affected, the social impacts of hazard exposure often fall disproportionately on the most vulnerable people in a society—the poor, minorities, children, the elderly, and the disabled. These groups often have the fewest resources to prepare for a flood, live in the highest-risk locations, occupy substandard housing, and lack the knowledge or social and political connections necessary to access resources that would speed their recovery. This paper presents two practical methods for identifying socially vulnerable groups and illustrates how the information they provide about social vulnerability, the drivers of vulnerability, and their spatial distribution in flood hazard zones can be used in the planning process to assist in identifying problems and opportunities, developing planning objectives, creating and evaluating management measures, and evaluating project alternatives. The two Social Vulnerability Analysis methods described are the Social Vulnerability Index and Social Vulnerability Profiling. Methods and procedures are illustrated using a hypothetical study area in Chatham County, GA, as an example.

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Preface

The U. S. Army Corps of Engineers (USACE) Campaign Plan has incorporated lessons learned from the events of Hurricanes Katrina and Rita in August 2006, which began with the announcement of the "12 Actions for Change," a set of concepts to guide USACE in transforming its priorities, processes, and planning. These actions formed the basis for a major transformation initiative to more sustainably solve problems that limit national welfare. The desired changes are addressed through four strategic themes: 1. a comprehensive and systems-based approach to mission execution, 2. implementation and integration of risk-informed decision-making, 3. better risk communication to the public and increased public involvement in risk reduction strategies, and 4. improved professional and technical competence.

The Systems Approach, with its focus on comprehensive solutions, applies broadly to all USACE activities. It incorporates anticipatory and adaptive management to improve and sustain human welfare over time. It places high priority on equitably protecting public health and safety, and the continued viability of natural systems. The focus of decision making will shift from individual, isolated projects to an interdependent system, and from an economic development focus to full consideration of social and environmental factors.

This report presents work completed for the Campaign Plan Systems Approach Multi-Objective Product Delivery Team. The team consists of Susan Durden, CEIWR; Dr. Ed Rossman, CESWT; Vechere Lampley, CESAD; and William Bailey, CESAS. The lead for the System Approach is Dr. Kathleen White, CEIWR and the Senior Project Manager is Gary House, CECW-CER. The primary authors of this report are Dr. Mark Dunning and Susan Durden. Significant contributions were made to the project by Dr. Susan Cutter and Dr. Chris Emrich of the University of South Carolina Hazard and Vulnerability Research Institute. Additionally, Mitch Horrie of CDM, and Laurie Griffith and Dr. Paul Koch of Marstel-Day LLC provided support and research for the project. Dr. Charles Yoe provided valuable input and insights. For further information, contact Susan Durden (703-428-9089, Susan.E.Durden@usace.army.mil) or Mark Dunning (703-966-2398, dunningcm@cdm.com).

Executive Summary

Social effects have long been part of water resources planning in the United States. Their importance has waxed and waned with the circumstances of the times. However, the experiences of Hurricanes Katrina, Rita, and Ike, as well as extensive flooding in the Upper Midwest, have again emphasized to the Nation the reality and significance of the social impacts of floods. One of the lessons of Katrina and Rita has been that the effects on socially vulnerable populations have been woefully overlooked and underestimated. While all people living in flood hazard areas are at risk, the social impacts of hazard exposure often fall disproportionately on the most vulnerable people in a society—the poor, minorities, children, the elderly, and the disabled. These groups often have the fewest resources to prepare for a flood, live in the highest-risk locations, occupy substandard housing, and lack the knowledge or social and political connections necessary to access resources that would speed their recovery. A focus on these disadvantaged populations also supports the federal government's efforts in addressing environmental justice concerns. As mandated in Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, federal agencies must disclose the distribution of social and environmental effects of federally funded actions on minority and poor populations and ensure that those groups receive the opportunity to be involved in agency decision making procedures.

If the Corps had accepted models for estimating the monetary costs and benefits of social effects, they could be part of the traditional benefit-cost analysis used in project evaluation processes. However, we do not yet have such models, so we identify social effects in other ways, quantifying effects when possible and describing them qualitatively when we cannot. Even if current limitations on quantification and monetization of effects restrict their role in benefit-cost analyses, information on social vulnerability is essential to enrich planners' understanding of issues and factors that are critical to developing sound plans.

This paper presents two practical methods for identifying socially vulnerable groups and illustrates how the information they provide about social vulnerability, the drivers of vulnerability, and their spatial

distribution in flood hazard zones can be used in the planning process to assist in identifying problems and opportunities, developing planning objectives, creating and evaluating management measures, and evaluating project alternatives. The two Social Vulnerability Analysis methods described are the Social Vulnerability Index (SoVI) and Social Vulnerability Profiling (SVP). Additionally, a number of supplemental social effects analysis tools are described (Appendix A) that can work in tandem with the SoVI or profiling methods. Methods and procedures are illustrated using a hypothetical study area in Chatham County, GA, as an example.

The Corps' emerging Flood Risk Management framework presents an ambitious vision of a collaborative, risk-informed decision process for managing flood risks, in which all parties have an understanding of risk and the actions that can be taken to reduce risks, and in which multifaceted solutions addressing economic damages, public safety, and environmental quality issues are sought, employing partnerships and collaboration at all levels of government with public and private stakeholders. Social vulnerability analysis can play an important role in this framework by focusing attention on the needs of vulnerable groups and providing information necessary to more completely address the full range of vulnerabilities facing these communities.

1 Introduction: What is Social Vulnerability, and Why is it Important to Corps Planners?

Social effects have long been part of water resources planning in the United States. Their importance has waxed and waned with the circumstances of the times. However, the experiences of Hurricanes Katrina, Rita, and Ike, as well as extensive flooding in the Upper Midwest, have again emphasized to the Nation and the world the reality and significance of the social impacts of floods. One of the lessons of Katrina and Rita has been that the social effects on vulnerable populations have been woefully overlooked and underestimated.

If the Corps had accepted models for estimating the monetary costs and benefits of social effects, they could be part of the traditional benefit-cost analysis used in project evaluation processes. However, we do not yet have such models, so we identify social effects in other ways, quantifying effects when possible and describing them qualitatively when not possible. Even if current limitations on quantification and monetization of effects restrict their role in benefit-cost analyses, information on social vulnerability is essential to help enrich planners' understanding of issues and factors that are critical in developing sound plans. This paper presents some practical methods for identifying socially vulnerable populations and suggests how such information can be productively used in the flood risk management planning and decision-making process.

1.1 Context and Key Terms

Vulnerability refers to the capacity for being damaged by hazards or the impacts from hazard events. For many years the Corps of Engineers has focused on quantifying the economic vulnerability of communities to risks from flooding and storm events. The damages to property that could be expected from such events form the basis for computing National Economic Development (NED) benefits and creating benefit-cost analyses for evaluating Federal flood damage reduction investment priorities under

the Principles and Guidelines (P&G) procedures.[1] However, relying on NED-related economic vulnerability to evaluate flood risk only captures part of the impacts of flooding and provides an incomplete picture of risks posed by hazards. Calls have increasingly been made for a fuller analysis of the vulnerabilities of communities beyond those captured in the NED account.[2] [3]

Social vulnerability refers to "the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist, or recover from the impact of a hazard" (Wisner et al. 2004). Social vulnerability is most apparent after a hazard event has occurred, when different patterns of suffering and recovery are observed among certain groups in the population, e.g., the aged, the poor, minorities (Cutter et al. 2000, Heinz Center 2000, Cutter and Finch 2003, Warner 2007). Such groups may not only be least prepared for an emergency but also may often live in more hazardous locations, in substandard housing, have the fewest resources, and lack knowledge and/or sense of political efficacy to claim access to resources to assist in recovery (National Research Council 2006, p. 73). Social Vulnerability Analysis (SVA) describes the relationship between social characteristics and vulnerability to hazards (better documenting who is at risk) and the distribution of tangible and intangible hazard effects (primarily focusing on impacts described in the Other Social Effects account).

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[1] It is presumed that the reader is aware of the four-account evaluation framework that is in effect under the "Economic and Environmental Principles and Guidelines for Water and Related Land Implementation Studies" (Water Resources Council 1983). For further details see ER 1105-2-100: Planning Guidance Notebook (USACE 2000).

[2] "Calculations of NED are meant to include all environmental and social benefits and costs for which monetary values can be obtained. The monetary focus on NED, however, does not give adequate consideration to unquantifiable environment and social values. Because of their nonmarket nature, environmental quality, ecosystem health, the existence of endangered species, and other social effects are not as easily quantified in monetary values. This limits formulation and acceptance of projects capable of striking a better balance between flood damage reduction or other water resources development and the environment" (Interagency Task Force on Floodplain Management 1994). "P&G…do not adequately reflect contemporary water resources planning principles and practices…Examples of specific revisions to the P&G which the committee recommends include: (1) movement away from the consideration of the National Economic Development (NED) account as the most important concern. Today, ecological and social considerations are often of great importance in project planning and should not necessarily be considered secondary to the maximization of economic benefits" (National Research Council 1999).

[3] Guidance set forth in the 2007 Water Resources Development Act, Section 2031, indicate that there will be increased emphasis on public safety, and a broader range of public benefits under the emerging principles and guidelines (P&G). Some specific P&G evaluation approaches called for in the Act include the use of the best available risk and uncertainty analysis principles and techniques, assessing and incorporating public safety in formulating alternative and recommended plans, and applying assessment methods that place value on projects for low-income communities.

> *"Socioeconomic status is a significant predictor...for physical and psychological impacts of disasters. [Vulnerable populations are]...less likely to prepare for hazards...less likely to respond to warnings; more likely to die, suffer injuries, and have proportionately higher material losses; have more psychological trauma; and face more obstacles during phases of response, recovery, and reconstruction."*
>
> *Institute for Business and Home Safety (2009)*

Overlaying the spatial distribution of vulnerable populations with hazard zones associated with flooding, storm surge, wind impacts, or other hazards using geographic information system (GIS) technology produces a Place Vulnerability Assessment (PVA) (Cutter et al. 2000) showing hazard hot spots with the greatest hazard potential and the greatest concentration of vulnerable populations. Such information provides valuable insights into the kind of preparedness and response measures needed to selectively target areas of high social vulnerability.

1.2 Objective

This report illustrates the use of Social Vulnerability Analysis in a Corps Flood Risk Management (FRM) context.[1] It shows how information about social vulnerability, the drivers of vulnerability, and their spatial distribution in flood hazard zones can be used in the planning process to assist in identifying problems and opportunities, developing planning objectives, creating and evaluating management measures, and evaluating project alternatives. This objective addresses the need to move beyond an NED-focused project development process to one that considers a broader range of issues.

1.3 Report Structure

Section 1 provides the overall context and objective of the project. Section 2 describes several key risks and risk management concepts integral to the emerging Corps risk-informed planning framework and presents a model of Social Vulnerability Analysis in this framework. Section 3 describes how social vulnerability issues can be incorporated into a risk-informed planning process. It describes the kinds of questions about social vulnerability that should be posed at each step of the Corps' six-step planning process, the kinds of tools that can help obtain answers to the

[4] The emerging FRM framework is described more fully in Section 2.

questions, and ways in which this information can be used in the planning step. Section 4 describes two methods for performing Social Vulnerability Analyses. The first method, the Social Vulnerability Index (SoVI), was developed by Cutter and Finch (2003) to illustrate the spatial variation in social vulnerability. SoVI identifies the most socially vulnerable populations and the source of their vulnerability. The second method, termed Social Vulnerability Profiling (SVP), provides a simple, straightforward way of characterizing socially vulnerable populations. Each method is utilized in an example to better illustrate computation procedures and potential use in a Corps FRM planning context. Section 5 continues the example begun in Section 4 and focuses more directly on using SVA in the six-step Corps planning process. Finally, Section 6 reflects on the applicability of SVA in Corps planning, as well as for other hazard management applications, and discusses how the current state of Social Vulnerability Analysis practice might be improved.

2 Flood Risk Management and Social Vulnerability Analysis

Risk is described as the likelihood and severity of adverse outcomes (Moser 2008) and can be considered to be a function of several factors (Figure 1):

- The hazard threat, which has a frequency of occurrence and intensity that can sometimes be described with a probability distribution (e.g., streamflows, storm intensity);
- Exposure of vulnerable valued assets (economic, social, and environmental) to the hazard;
- Resultant consequences (impacts) (e.g., property damages, loss of life, social disruption, environmental damages); and
- Consequences that can be mediated by the assets' resilience (i.e., factors that affect their ability to respond to and recover from the hazard).

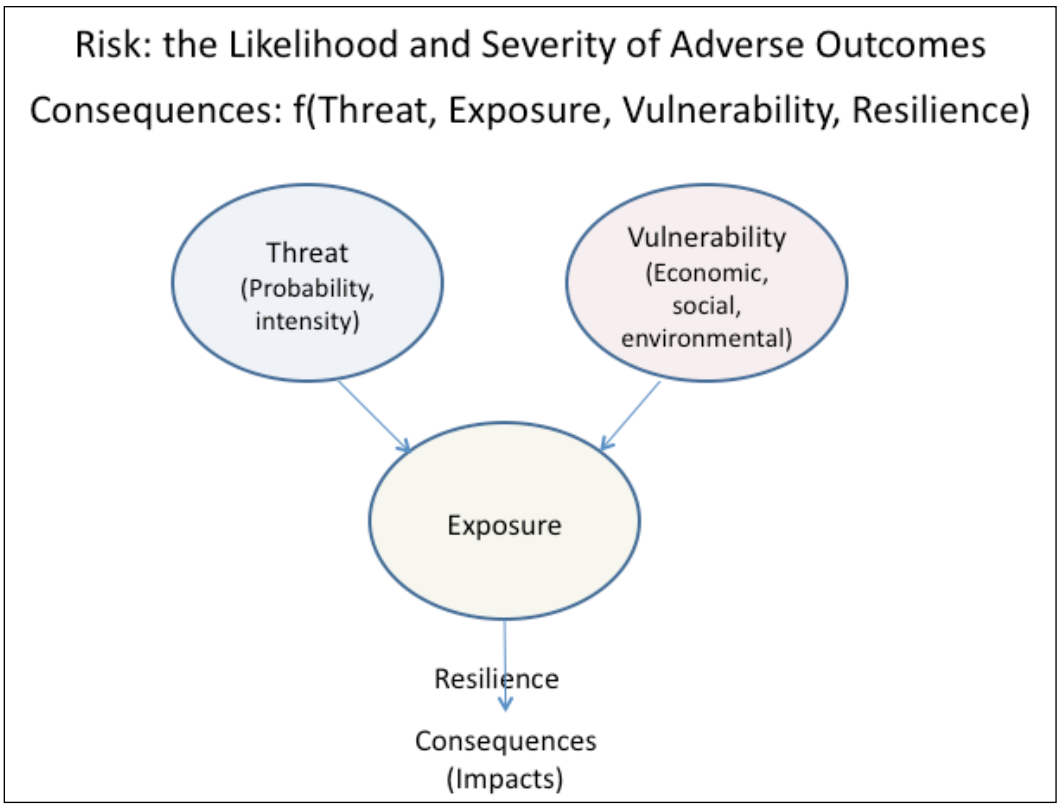

Figure 1. Factors affecting risk.

Figure 2. Flood Risk Management Program. (From Rabbon 2007.)

Risk can be managed[1] by operating on one or more of these factors: reducing the threat, removing or protecting vulnerable assets from exposure to the threat, and improving resilience. The Corps' emerging Flood Risk Management (FRM) framework[2] (Figure 2) (http://www.nfrmp.us/index.cfm) is evolving to more completely and comprehensively consider each of these factors as they apply to the existing situation (existing risk), to the range of potential risk management solutions, and to the residual risk[3] that remains after proposed FRM solutions—and to recognize that such awareness needs to be factored into discussions of, and ultimately agreements about, the level of risk to be tolerated.[4]

[1] (Moser 2008).

[2] The emerging FRM framework is described more fully in Section 2.

[3] "Residual risks derive from the exposure of people, property, infrastructure, the ecosystem, the local economy, and social and cultural aspects of the region to loss from events that exceed the design. [The Risk Informed Decision Framework] stresses that residual risks exist and that planning alternatives can rarely, if ever, reduce the likelihood of their loss to zero." (Harper et al. 2009, p.10)

[4] The Corps has traditionally described existing risk but has not emphasized the residual risk of flood damage reduction solutions, instead often using the term *level of protection provided.* Introducing the concept of residual risk into flood management increases the attention that must be paid to how much risk people are willing to accept. "In the past an output of the plan formulation process was the identification of a level of protection. If the Corps is transitioning to a flood risk management agency, then the new choice is not of a level of protection but of a level of residual risk that can be tolerated based on the costs of further reductions in the risk" (Yoe 2008).

Hydrologic and hydraulic analyses have done an excellent job of helping decision makers and the public understand the physical aspects of the flood threat. Social vulnerability analysis in the emerging FRM framework (Figure 3) is concerned with helping to improve the understanding of social vulnerabilities and consequences. It describes who is likely to be most vulnerable to flood threats, the kinds of consequences that can be expected for vulnerable populations, and the resilience of populations (i.e., how rapidly and completely they are likely to recover from a flood event).

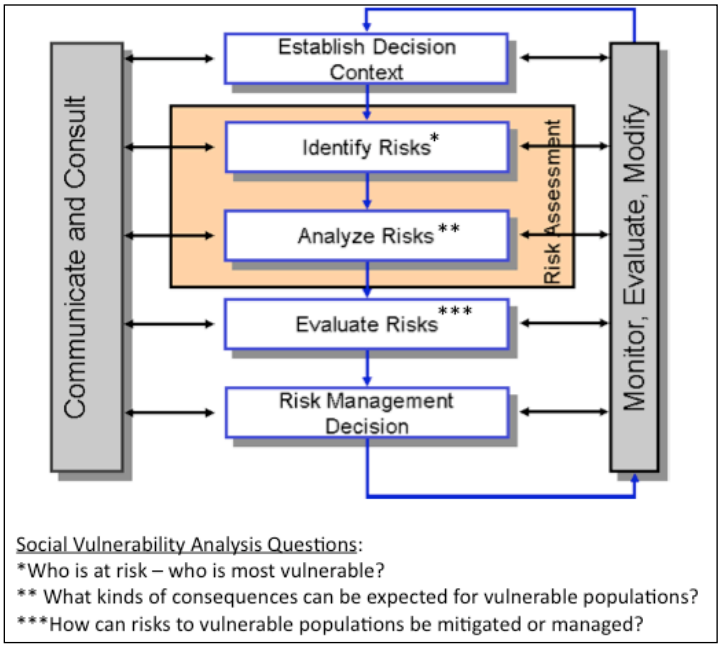

Figure 3. Social Vulnerability Analysis (SVA) in the risk framework.

2.1 Describing Who Is Vulnerable

While all people living in flood hazard areas are vulnerable, certain social characteristics are more likely to be associated with more severe consequences of exposure to floods (National Research Council 2006, p. 73). Social impacts of hazard exposure often fall disproportionately on the most vulnerable people in a society—the poor, minorities, children, the elderly, and the disabled. These groups often have the fewest resources to prepare for a flood, live in the highest-risk locations in substandard housing, and lack the knowledge or social and political connections necessary to take advantage of resources that would speed their recovery. Some of the most common vulnerability characteristics are summarized in Table 1 and noted below.

Table 1. Social vulnerability factors and their implications during and after floods.

Vulnerability factor	During event	Recovery (Resiliency)
Low income/poverty level	Lack of resources may complicate evacuation	Lack of resources may hinder ability to recover
Elderly/very young	Greater difficulties in evacuation, more health and safety issues, potential for higher loss of life	May lack resources, willingness, ability to rebound
Disabled	Greater difficulties in evacuation, special health and safety issues, potential for higher loss of life	Lack of facilities and medical personnel in aftermath may make it difficult to return
Female-headed households	Lack of resources and special needs may complicate evacuation	Lack of resources may hinder ability to recover
Minorities	Lack of influence to protect interests; lack of connections to centers of power or influence	Lack of influence to protect interests; lack of connections to centers of power or influence
Occupants of mobile homes/renters	Occupy more vulnerable housing	Potential displacement with higher rents
Transient/homeless	Difficult to locate and provide information to; difficult to estimate numbers	

Figure 4. Much of the worst flooding from Hurricane Katrina occurred in lower income neighborhoods (Corps of Engineers photo).

- **Low Income/Poverty Households**: Poorer households are more likely to occupy risky locations and to be in housing that is older and in substandard condition. Poorer households may lack resources such as cars to evacuate in a flood emergency and have less ability to absorb losses from a flood, less access to insurance, fewer resources to provide a cushion for a long recovery period, and less access to social networks that can lobby on their behalf for assistance (Figure 4). Lower income

jobs appear to be at greater risk of being lost after a flood event (Laska and Morrow 2006). Low income is highly correlated with low education, and the less educated tend to be less well informed about developing hazards.

- **The Elderly**: The elderly are likely to have greater difficulty in evacuating from homes and may lack the ability, stamina, or resources to bounce back after the event. Additionally, the frail elderly may be in nursing homes or hospitals, which places the burden for their safety in a flood emergency on others (Figure 5).

Figure 5. Elderly resident being evacuated in the aftermath of Hurricane Katrina. (Corps of Engineers photo.)

- **The Very Young**: The very young may pose additional difficulties in evacuating from homes and may be more susceptible to flood-borne diseases.
- **The Disabled**: Like the elderly, the disabled are likely to have greater difficulty in evacuating during a flood emergency.
- **Female-Headed Households**: Females who head households are more likely to have fewer resources and bear special burdens for child care that limit options for employment.
- **Minority Group Status**: Independent of income, minority groups are likely to occupy more vulnerable positions in the social order, more likely to be located in hazardous locations, and less likely to have connections to outside centers of power and influence.
- **Occupants of Mobile Homes/Renters**: Mobile homes are likely to be situated in hazardous locations and be of more fragile construction

The New Orleans, LA, Experience

Hurricane Katrina struck the Louisiana, Mississippi, and Alabama coasts on August 29, 2005. The devastation of the hurricane and the flooding of the City of New Orleans produced by levee breaks from the hurricane created a catastrophe without precedent in the United States. Social scientists have reported a number of findings that bear on issues of social vulnerability.

***Low Income/Poverty**: Laska and Morrow (2006, p. 18) report that pre-Katrina about one-quarter of the population lived below the poverty level, compared to about 13 percent nationally. About 20 percent of households lacked automobiles, and the city ranked second among the 50 largest cities in the United States in the extent to which its poor families were clustered in poor neighborhoods.*

***The Elderly**: In New Orleans, while persons 60 years of age or older made up 15 percent of the population in 2000, they accounted for 70 percent of the deaths associated with Katrina, and while those 70 or older made up 9 percent of the population, they accounted for almost 50 percent of the dead (Laska and Gramling 2008, p. 80).*

***Female Headed Households**: Laska and Gramling (2008, p. 37) point out that the group most severely impacted by Katrina and its aftermath were lower-income, predominately African-American, female-headed households. Many of these households were displaced from their homes, and many continue to live as displaced persons.*

***Minority Group Status**: Laska and Morrow (2006, p. 18) note that African Americans in New Orleans were four times more likely to have lost their jobs post-Katrina than white workers and that, when income levels were factored in, the difference increased to seven times for the lowest-income African-American workers.*

Planners and emergency managers need information about who is vulnerable and the kinds of consequences that can be expected when they are exposed to flooding threats so that appropriate plans for reducing risks and mitigating consequences can be made.

that is more vulnerable to high winds and flowing water than traditional dwellings. Renters run a greater risk of displacement in the aftermath of a flood event, as rents of existing intact housing often increase, making it difficult for former residents to return or remain.

- **Transient/Homeless Populations**: These populations are difficult to locate when emergency events occur, difficult to communicate with about emergencies, and difficult to evacuate.

2.2 Understanding the Consequences: Identifying the Social Effects of Flooding

Disaster research studies have revealed much about the social effects or human dimensions that are likely to occur during and after a flood. Personal impacts include loss of life, sickness, injury, loss of employment, loss of valued personal items, loss of a sense of place and a sense of security, and family stress and disruption (Erikson 1976, Allee et al. 1985, Quarantelli 1988, Heinz Center 2000, Tapsell et al. 2002, World Health Organization 2002, National Research Council 2006). Community impacts include disruption of community services and impairment of community economy, decline in property values, and deterioration in physical and social infrastructure (Heinz Center 2000, Drabek 1986). Political tensions can also arise as competing visions of reconstruction emerge and residents of the local culture collide with outside bureaucratic relief organizations that arrange temporary housing and other services (National Research Council 2006). Table 2 summarizes the social effects most frequently associated with flood events and their aftermath.

Post-traumatic stress disorder, a major social effect of flooding or any natural or human-induced disaster, manifests as anxiety, depression, psychosocial disturbances, and, in severe cases, suicides. The same major stresses continually surface in the research: trauma from the flood event, geographic displacement, loss of possessions, and problems with insurance. One United Kingdom survey conducted in 2000 suggested that anxiety and depression persisted nine months or more after the physical damage of flooding had been repaired (Hendy 2008). United States flood research data also have shown a statistically significant increase in suicide rates four years after a flood (World Health Organization 2002).

Table 2. Potential social effects from flooding.
(From Dunning and Durden 2009.)

Social factor	Potential social effects from flooding and/or flood damage reduction approaches
Health and Safety	Residents feel less safe in their living space/community. Vector-borne diseases increase. Residents feel traumatized by the flood event. Injuries and loss of life are experienced.
Economic Vitality	Business closures and loss of wages gradually cause economic deterioration after a flood. Recovery may stimulate business growth; reconstruction may create a temporary building boom; influx of construction workers may raise rents and create housing shortages.
Social Connectedness	Greater incidence of cooperative behavior during and immediately after a flood occurs as people pull together to face common problems. Disruption and loss of valued personal relationships create feelings of loss and disconnectedness from neighborhoods. ("Things will never be the same again.") Extended relocation away from neighborhoods and homes creates feelings of isolation and disconnectedness, leading to increases in health problems, crime, and marital problems. Community civic culture and capital are likely to be challenged by demands of flooding; communities with strong civic cultures are better equipped to cope.
Identity	Flood losses and dislocation may disrupt people's sense of cultural security and identity.
Social Vulnerability and Resiliency	Elderly, poor, disabled, minorities, and children may suffer greater relative harm and be less likely to bounce back. Disruption and relocation may create dependency and loss of independence.
Participation	Local modes of decision making and participation may clash with flood-recovery processes. Development of flood damage reduction strategies offers opportunities to increase local participation and trust.
Leisure and Recreation	Leisure and recreation activities and opportunities may be disrupted. Flood damage reduction approaches may constrain, or in some cases enhance, valued leisure and recreational pursuits.

In New Orleans after Hurricane Katrina, the number of residents with mental illness doubled after the storm, with 30 percent of residents exhibiting some form of mental illness (Hurricane Katrina Community Advisory Group 2006). A *New York Times* article from June 20, 2006, characterizes New Orleans post-Katrina as "experiencing what appears to be a near epidemic of depression and post-traumatic stress disorders, one that mental health experts say is of an intensity rarely seen in this country. It is contributing to a suicide rate that state and local officials describe as

close to triple what it was before Hurricane Katrina struck and the levees broke 10 months ago" (Saulny 2006). Additionally, the article notes that many residents continued to experience "low-grade but persistent feelings of sadness, hopelessness, and stress-related illnesses" (Saulny 2006).

A United Kingdom study of the social impacts of flooding in the UK cities of Carlisle in 2005 and Hull in 2007 focused on some of the often-ignored effects of flood trauma on individuals. A partnership project, Communities Reunited, was established to voluntarily provide support to people affected by the floods. The support team quickly identified needs associated with the upset of people's normal routines, flood-related insurance claims, financial and debt problems, and physical and mental health-related issues (Hendy 2008).

Communities Reunited provided numerous support services that included a humanitarian advice and support center in the city center, a phone hotline, a newsletter, and "caravans" that provided refreshments and listening support to anxious flood victims. Major issues that slowed people's recovery process included the frustration of navigating the insurance claim process and dealing with incompetent contractors, the disappointment of delayed and denied claims, and the accumulation of debt as life savings were used in an attempt to speed up the recovery process. Trauma resulted from being trapped in a stressful environment with no ability to control events. Effects sometimes were exacerbated by other life challenges related to chronic medical issues, family bereavement, job security, divorce, and miscarriage (Hendy 2007).

A 2006 national study of flood communities in Scotland (Werrity et al. 2008) concluded that the intangible impacts—such as stress from the flood itself, anxiety and discomfort of living in temporary housing, and effort spent dealing with insurers and builders—were more severe than the tangible impacts of a flood. The study also showed that such immediate intangible impacts were more severe than lasting intangible impacts, such as fear of a future flood or loss of irreplaceable possessions. Households with insurance reported higher levels of stress, and households with lower incomes also reported more anxiety and greater health impacts. The single greatest impact was the trauma of experiencing the flood event itself and its immediate aftermath, which was disproportionately experienced by the elderly and other vulnerable residents. Focus group participants also reported that it was difficult to maintain family cohesion when children

lived in hotels or stayed with grandparents and that relationships within the family had suffered (Werritty et al. 2008). Similar disappointment caused by the loss of friends and acquaintances who evacuated from New Orleans after Katrina is echoed in a news article quoting one resident commemorating the second anniversary of Hurricane Katrina: "Most of my good friends are not here any longer. That is one of the things that is wrong. The fabric of this city will never be the same" (Nossiter 2007).

2.3 Understanding Resilience as a Mitigating Factor

Resilience refers to the capability to cope with and recover from a traumatic event. Other things being equal, the greater the social vulnerability of groups, the less their resilience, since the factors that contribute to vulnerability often reduce the ability of groups to recover from a disaster (Miletti 1999). Some of the factors that are likely to contribute to a community's resilience are shown in Table 3.

Table 3. Community resilience factors. (After Cutter et al. 2008.)

Community resilience category	Potential factors
Ecological	Presence of ecological buffers and protected areas (e.g., wetlands)
Social	Social networks, social capital,[1] civic infrastructure
Economic	Economic vitality, municipal finance and revenues
Institutional	Participation in hazard reduction programs, hazard mitigation plans, emergency response plans, continuity of operations plans, zoning and building standards
Infrastructure	Critical infrastructure, transportation network
Community competence	Risk communication, quality of life

[1] Social institutions such as families and public and private organizations play an important role in mediating the effects of disasters (Boruff et al. 2005). The concepts of social capital (Putnam 1993) and civic infrastructure (National Civil League 1999) help describe the robustness of such institutions. Communities with well-functioning and interdependent networks of formal and informal organizations are likely to be more resilient than communities with weak civic infrastructures and low social capital: "the networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit" (Putnam 1993, p. 67). The Saguaro Seminar (http://www.hks.harvard.edu/saguaro/), a project developed by James Putnam to further understanding of social capital dynamics, has developed a number of surveys that provide consistency of results and begin to provide comparative data about social capital conditions in communities. They include the 2000 Social Capital Community Benchmark Survey, the 2006 Survey, and a Short-Form Survey, as well as an informative Evaluation Guide for conducting social capital assessments. Examples of social capital and civic infrastructure in action can be seen in Cedar Rapids, IA, and its not-for-profit Corridor Recovery partnership (www.corridorrecovery.org) among government, business, and faith-based organizations to coordinate and assist with the recovery from devastating floods experienced by the community in 2008. The partnership has functioned to mobilize and coordinate volunteers to assist with rebuilding, providing information on obtaining assistance, leveraging resources, and advocating for Federal resources.

While various factors can exert an influence on a community's ability to cope with and rebound from a hazard event, there is no precise way of quantifying their influence on reducing negative consequences of flooding. A recommended approach is to engage communities in discussions about the meaning and relevance of such factors for risk management planning. The National Oceanic and Atmospheric Administration (NOAA) has taken such an approach in the development of a draft self-assessment Resiliency Index that community leaders, planners, and engineers in coastal communities are using in several pilot tests to assess their community's ability to recover from a disaster and to help identify actions that can increase community resiliency. The assessment tool examines six categories of resilience factors in each community: critical infrastructure, transportation, community plans and agreements, mitigation measures, business plans, and social systems (Table 4) (Emmer et al. 2008). (http://www.csc.noaa.gov/tools/index.html). It uses the information to engage with local leaders about disaster management planning.

Community leaders, planners, and engineers have used information derived from the Resiliency Index in four coastal communities to date (Dauphin Island, AL; Gulf Shores, AL; Ocean Springs, MS; and St. Tammany Parish, LA) and have plans to implement it in five additional communities in the future.

2.4 Section Wrap-up and Look Ahead

Experience and research show that the social effects of floods are real and significant and that some groups are more likely to incur more negative consequences. Social vulnerability analysis describes who is likely to be especially at risk from flood effects and focuses on the special needs of such groups that should be taken into account as part of the FRM planning process. Factors that contribute to a community's resilience are important in helping to reduce the negative consequences of flooding. Ways to enhance these factors also need to be addressed in FRM plans. The next section discusses how information about social vulnerability can be addressed in the Corps planning process.

Table 4. NOAA's Draft Coastal Resiliency Index: A community assessment. (After Emmer et al. 2008.)

Factor	Assessment questions
Critical Infrastructure and Facilities	Are critical infrastructure/facilities likely to be functional after a disaster? Critical Infrastructure: sewage treatment system; power grid; water purification system; transportation/evacuation routes Critical Facilities: City Hall; police station; fire station(s); communications main office or substations; emergency operation center; evacuation shelter(s); hospital(s)
Transportation Issue	Will flood-prone areas and vital facilities (tunnels, roads in low-lying areas, bridges, roads blocked by storm debris, etc.) be operational within one week? Is public transportation available to assist evacuation? Is there more than one evacuation route?
Community Plans and Agreements	Does your community have… A certified floodplain manager; early flood warning system; formally trained planning commissioners; planning staff with AICP credentials; FEMA-approved and state EMS-approved mitigation plan (revised in the past two years); MOUs or MOAs with neighboring communities; comprehensive plan or strategic plan that addresses natural disasters; American Planning Association or state APA chapter; American Society of Civil Engineers (ASCE) state or local section; American Public Works Association; first-hand experience with disaster recovery within the last 10 years?
Mitigation Measures	Elevation of residential, nonresidential buildings, or infrastructure to National Flood Insurance Program standards for your community Relocation of buildings and infrastructure from flood-prone areas Flood-proofing of nonresidential structures Education programs about mitigation options for your community Acquisition of repetitive loss structures or infrastructure Incentives-based mitigation measures Adoption of the most recent International Building Codes Hiring certified building inspectors Staffing an adequate number of people to enforce building codes
Business Plans	Generators Backup options for basic needs (water, sewer, and communications) Plans to bring in staff to help reopen the business Plans for restocking
Social Systems	Strong faith-based networks Cultural identity (Hispanic, Asian, or other ethnic communities) Neighborhood associations Business cooperative or working relations (industries that employ many residents, Chamber of Commerce, other business-related networks, etc.) Strong civic organizations (Kiwanis Club, Rotary Club, etc.)
Other resiliency indicators	Additional resiliency indicators that you think should be included in this assessment?

3 Using Social Vulnerability Analysis in the Planning Process

3.1 An Evolving Planning Framework

The Corps' Engineering Circular (EC) 1105-2-409, *Planning in a Collaborative Environment* (USACE 2005), made a number of major changes in Corps planning policy:

- Collaborative planning activities with other Federal agencies and solutions that reflect issues beyond traditional Corps responsibilities will be given budget priority;
- Plans no longer need recommend the NED plan (though cost-sharing policies concerning NED plans remain in effect). Any alternative plan may be recommended if, on balance, it has net beneficial effects in the four P&G accounts. Planning reports must discuss and display the beneficial and adverse effects of each plan in each P&G account and compare the effects across plans.

The emerging FRM framework also presents an ambitious vision for a collaborative, risk-informed decision process for managing flood risks in which all parties have an understanding of risk and actions that can be taken to reduce risks and in which multifaceted solutions addressing property protection, public health and safety, and environmental quality issues are sought, employing partnerships and collaboration at all levels of government with public and private stakeholders (House 2008, Durden and Dunning 2008).

> *"To significantly improve public safety, we are pursuing a level of public education at which our fellow citizens are so well informed they are able to assume responsibility for decisions they make about where and how they want to live and work. We then can engage in a comprehensive and multi-government and private citizen collaborative process to manage flood risk to achieve levels of tolerable risk."*
>
> *MG Don Riley, 2008*

Together, these innovations in Corps planning policy provide a more fruitful opportunity to productively employ Other Social Effects (OSE) analysis in general and Social Vulnerability Analysis in particular to help develop FRM plans that more completely address the full range of vulnerabilities facing at-risk communities. In particular, SVA can be used in the following key planning functions:

- **Presenting the problem**: Social Vulnerability Analysis provides an opportunity to characterize existing flood risk in ways that meaningfully and more comprehensively describe flooding impacts on people and communities and call attention to reducing the exposure of and consequence to vulnerable populations. Social vulnerability information can provide added depth and dimension and ensure that the problem is accurately and fully described.
- **Providing input to planning objectives**: Planning objectives are the distillation of a process of identifying problems, needs, and opportunities. In this process, information about who is affected and how they see the situation is critical. Social Vulnerability Analysis can draw attention to particularly vulnerable groups in the project area and can help ensure that the interests of those who may be most vulnerable to risks are included in the process of providing input to planning objectives (Creighton 2005, Creighton et al. 2009).
- **Formulating and evaluating alternatives**: Specific management measures that address the exposure of vulnerable groups may require a different set of management measures than the Corps is used to including in its projects. In addition, the criteria used to evaluate plans should reflect meaningful measures of the community's social vulnerability.
- **Helping to crystallize important choices**: Communicating the socioeconomic implications of alternatives and helping stakeholders to understand them and explore the consequences on their situations and interests can help differentiate the choices that alternatives present. The people affected by floods are in the best position to represent their vulnerability and concerns. There should be a special responsibility to ensure that those stakeholders most vulnerable or at risk are afforded the opportunity—even provided special assistance—to participate in the exploration of alternatives.

Table 5 summarizes the Corps' six-step planning process and identifies key questions that the social analyst should be addressing through Social

Vulnerability Analysis.[1] Section 4 presents an example to further illustrate the approach and provides a detailed explanation of two SVA tools identified in the table: the Social Vulnerability Index and Social Vulnerability Profiling. Appendix A provides a short description of the other tools referenced in the table.

Table 5. Applying Social Vulnerability Analysis (SVA) in the Corps planning process: Key SVA questions and tools (Dunning and Durden 2009).

Step 1 - Specify problems and opportunities	
Desired Output of Analysis	Identification of vulnerable groups. Problems, preferences of vulnerable groups; inputs to planning objectives
Key SVA Questions	What groups are especially vulnerable? Who are they? Where are they located in the project area? What factors limit the resiliency of the area? What are the needs and interests of vulnerable groups as relates to water resources issues?
Tools	Social Vulnerability Index (SoVI), Social Vulnerability Profiling (SVP), stakeholder identification methods, workshops, interviews, historical analysis, content analysis
Step 2 – Inventory and forecast conditions	
Desired Output of Analysis	Descriptions of current and future state of social conditions of concern to stakeholders in the absence of a water resources solution
Key SVA Questions	What is the current risk in general and to vulnerable groups? What are likely impacts of events of various magnitudes with special focus on vulnerable groups? How well is the risk understood by those who are at risk?
Tools	Independent studies and projections, focus groups, Delphi panel, workshops, charrettes
Step 3 – Formulate alternatives	
Desired Output of Analysis	Descriptions of desired future social conditions; rankings and priorities among desired future conditions; specific management measures required to achieve a desired social future condition and why measures are preferred.
Key SVA Questions	What kinds of measures can best address the needs and interests of vulnerable groups?
Tools	Visioning workshops, focus groups, charrettes, interviews
Planning Steps 4, 5, 6 – Evaluate, compare, select plans	
Desired Output of Analysis	Descriptions of plans' effects on social conditions of concern; evaluation of each plan's adequacy in contributing to desired future social conditions
Key SVA Questions	What risk, risk reduction, and residual risk are associated with each plan? What is the distribution of risk; what groups are most at risk; what are social impacts to include benefits, costs, and residual risks associated with measures, plans, and alternatives? How do plans compare with respect to completeness, effectiveness, efficiency, and acceptability (including Tolerable Level of Risk)?
Tools	Workshops, focus groups, expert panels, charrettes

*Tools referenced are those that can supplement the information provided by Social Vulnerability Analysis methods described in Section 4 and are described in Appendix A.

[1] The presentation of the Corps planning process steps is based on that provided in the OSE handbook (Dunning and Durden 2009), and it is recommended that readers consult the handbook to obtain a fuller treatment of the role of social effects analysis in each phase of the Corps six-step planning process (http://www.iwr.usace.army.mil/docs/iwrreports/09-R-4.pdf).

Social vulnerability analyses and methods can also be used to support environmental justice (EJ) analyses performed not only by the Corps but also other federal agencies in their programs, policies, and activities. Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, requires all federal agencies to identify and address disproportionately high adverse health and environmental impacts of its programs on minority and low-income populations. Social Vulnerability and EJ analyses are complimentary endeavors because both seek to identify and disclose the distribution of socially and environmentally vulnerable populations, thereby allowing for their proportionate treatment to be more easily addressed in the decision-making process.

3.2 Section Wrap-up and Look Ahead

Social Vulnerability Analysis can enhance Corps FRM planning by more comprehensively and meaningfully describing flood risk and its consequences on vulnerable populations and by providing opportunities to use such information to formulate appropriate risk reduction measures. A variety of tools are available to perform Social Vulnerability Analyses in each step of the Corps planning process.

The next section provides an in-depth look at two methods for identifying vulnerable groups: the Social Vulnerability Index and Social Vulnerability Profiling.

4 Performing Social Vulnerability Analyses Using the Social Vulnerability Index and Social Vulnerability Profiling

4.1 Introduction

The first step in performing Social Vulnerability Analysis is detecting the presence and location of socially vulnerable groups. Two methods for accomplishing this task are presented in this section: the Social Vulnerability Index (SoVI) and Social Vulnerability Profiling (SVP). Both methods employ census data. The section describes each method and illustrates its application using census tracts in Chatham County, GA, as an example. This example is carried forward in Section 5 to illustrate the application of Social Vulnerability Analysis in the FRM process. Section 4 concludes with an assessment of each method's primary uses as a planning tool.

4.2 SoVI Overview

The Social Vulnerability Index, originally formulated by Cutter et al. (2000), is a comparative metric that provides a snapshot of an area's relative social vulnerability to hazard exposure. The index is created by synthesizing socio-economic variables[1] through a process called Principal Components Analysis.[2] The variables employed to create the index were selected based on extensive disaster research and social science research. Table 6 presents the variables employed in the SoVI and notes the aspects of vulnerability with which they are most likely to be associated. Computational procedures for creating a SoVI are described in Appendix B.

[1] The original SoVI formulation used county-level data and employed 42 variables. For smaller areas such as census tracts, the method employs 32 variables owing to the lack of census data coverage at smaller units (see Cutter et al. 2009, Appendix B).

[2] Principal Component Analysis (PCA) involves a mathematical procedure that transforms a number of possibly correlated variables into a smaller number of uncorrelated variables called *principal components*. The first principal component accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible (Dunteman 1989).

Table 6. Socioeconomic variables used in the SoVI. (From Cutter et al. 2009.)

Variable name	Description	Vulnerability dimensions
MEDAGE	Median age	Age
QKIDS	Percent of population under 5 years of age	Age
QPOP65	Percent of population 65 and over	Age
QSSBEN	Percent of population collecting social security benefits	Age, income/poverty
QBLACK	Percent African American	Minority status
QINDIAN	Percent Native American	Minority status
QASIAN	Percent Asian and Hawaiian Islanders	Minority status
QSPANISH	Percent Hispanic	Minority status
MIGRA	Foreign born	Minority status
NRRESPC	Per capita residents in nursing homes	Age, disabled
HOSPTPC	Per capita number of community hospitals	Disabled
PHYSICN	Number of persons per 100,000 population employed as healthcare practitioners and technical occupations	Disabled, employment
QRENTER	Percent renter-occupied housing units	Mobile Homes/renters
QMOHO	Percent of housing units that are mobile homes	Mobile Homes/renters
PERCAP	Per capita income	Income/poverty
MHSEVAL	Mean value of owner-occupied housing units	Income/poverty
M_C_RENT	Mean contract rent	Income/poverty
QRICH	Percent of households earning $100,000 or more	Income/poverty
QPOVTY	Percent living below poverty level	Income/poverty
PPUNIT	Average number of people per household	Income/poverty
QCVLUN	Percent civilian unemployment	Employment
QCVLBR	Percent of population participating in the labor force	Employment
QAGRI	Percent employment in farming, fishing, and forestry occupations	Employment
QTRAN	Percent employment in transportation, communications, and other public utilities	Employment
QSERV	Percent employed in service industry	Employment
QFEMLBR	Percent females participating in the labor force	Employment, gender
QFEMALE	Percent female population	Gender
QFHH	Percent female-headed household, no spouse present	Gender, income/poverty
QED12LES	Percent of population 25 years or older with no high school diploma	Education
HODENT	Number of housing units per square mile	Density
QRFRM	Percent rural farm population	Density, rural status
QURBAN	Percent urban population	Density, urban status

Principal component analysis statistically combines a number of dimensions of highly correlated variable measures of social vulnerability into a smaller number of uncorrelated variables called principal

components. The contribution of each principal component to vulnerability is then calculated. These several dimensions are then summed to create an index value that represents an area's social vulnerability. The index values can then be compared with the scores of other areas included in the data set. SoVI scores are generally expressed as standard deviations (z-scores) or quintiles to emphasize their relative value. While the original Social Vulnerability Index was calculated at the county level, it can now be calculated for cities, census tracts, and census block groups (Cutter et al. 2006, Burton and Cutter 2008). The SoVI has been extensively tested to determine temporal consistency using decadal census data from 1960–2000 (Cutter and Finch 2003) and to establish the robustness of downscaling to smaller geographic units (Schmidtlein et al. 2008).

Figure 6 shows a SoVI distribution computed for census tracts in the Corps' South Atlantic Division (SAD). The development of the SoVI for SAD is described in Appendix C.[1] The census tracts colored pink or red have SoVI scores that place them at the upper ends of the distribution of social vulnerability (i.e., greater vulnerability). In contrast, the tracts colored light blue or dark blue have social characteristics that place them on the lower end of the distribution for social vulnerability. The interpretation of the SoVI is that, other things being equal, a red- or pink-colored tract has more of the characteristics associated with social vulnerability that would place it at higher risk of incurring more and/or more severe negative social impacts should a hazard event occur than the tracts colored light or dark blue. Figure 7 illustrates this concept using the normal distribution and z-scores.[2] Using the criteria shown in the map in Figure 6 (i.e., scores ≥ 0.5 standard deviation) approximately 30 percent of tracts would be classified as having more of the characteristics associated with higher social vulnerability than the other tracts. Similarly, approximately 30 percent of the tracts would be classified as having fewer social vulnerability characteristics on the basis of having SoVI scores ≤ 0.5 standard deviations.[3]

[1] Appendix C presents the results of a preliminary effort to develop a simplified SoVI methodology.

[2] Z-scores indicate how many standard deviations an observation is above or below the mean and provide a way of identifying unusually vulnerable or unusually invulnerable areas. The z-score is easily computed as $z = x - \mu/\sigma$ where x is the value of the observation, μ is the mean of the population, and σ is the standard deviation of the population.

[3] The choice of the z-score level to differentiate highly vulnerable areas from areas of "average" vulnerability is arbitrary. While common scientific usage considers scores of ± 2 σ to be in a "normal" range, and restricts the extraordinary to 5 percent (or fewer) of cases, the SoVI methodology generally employs a less restrictive score to call attention to a greater number of potentially vulnerable areas.

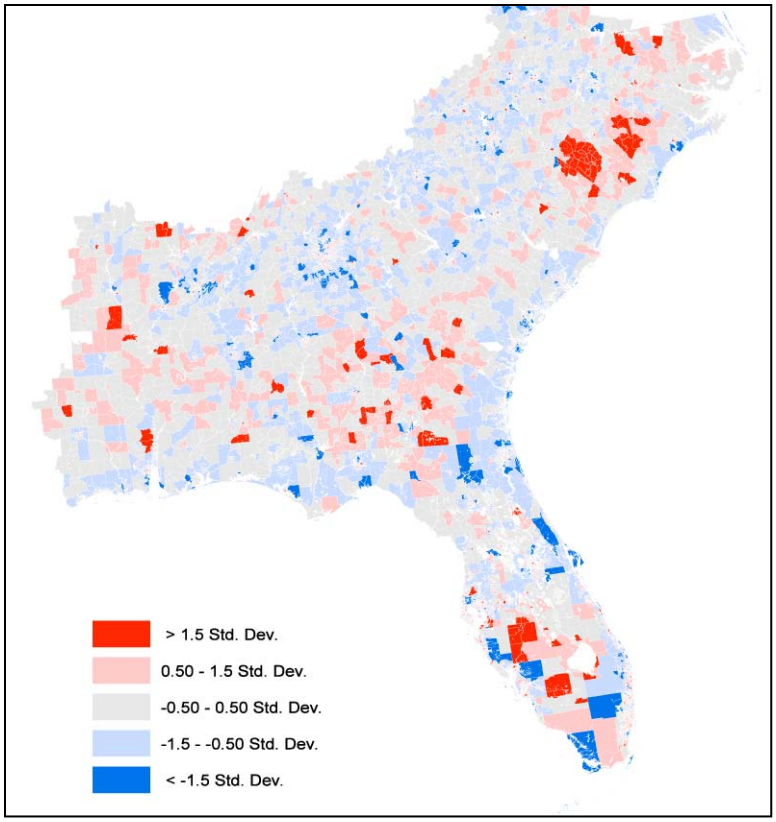

Figure 6. South Atlantic Division SoVI tract scores.

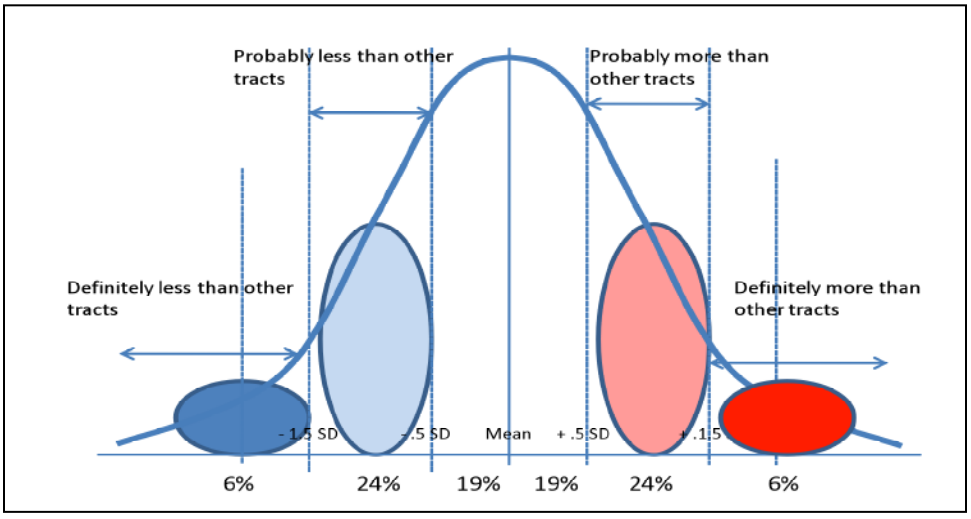

Figure 7. Using Z-Scores to determine social vulnerability categories.

4.3 Social Vulnerability Profiling

The Social Vulnerability Profiling method is a simpler form of identifying vulnerable populations than the SoVI. Like the SoVI procedure, a SVP assembles basic social indicators of vulnerability from census data to draw

inferences about the potential for the distribution and magnitude of social effects of exposure to a hazard. However, in contrast to the SoVI, Social Vulnerability Profiling generally uses fewer variables and does not employ a statistical procedure to generate vulnerability dimensions. For example, Table 7 shows the vulnerability factors discussed in Section 2 together with a census social indicator for each factor.[1]

A vulnerability profile is performed by obtaining the relevant census information for each of the indicator variables for the project area at the appropriate level of geography (e.g., census tract, block group, etc.). Once

Table 7. Social Vulnerability Profile indicator variables.

Vulnerability factor	Potential social indicators	Source	Equation
Low Income/ Poverty Level	Percent of population living below poverty level 2000	SF3, Table P87: Poverty status in 1999 by age SF1, Table P1: Total population	P87/P1
Elderly/Young	Percent of population ≥65 years of age 2000 Percent of population <5 years of age 2000	SF1, Table P12: Sex by age	P12/P1
Disabled	Disability status	SF3, Table P42: Disability status by employment status for the civilian noninstitutionalized population 5 years and older	
Female-headed Households	Percent female-headed households, no spouse present 2000	SF1, Table H17: Tenure by household type (including living alone) by age of householder	
Minorities	Nativity Proportion of minority residents Proportion of foreign born	SF3, Table PCT12: Nativity by language spoken at home, by ability to speak English for the population 5 yrs and older	
Occupants of Mobile Homes/ Renters	Percent of housing units that are mobile homes 2000 Percent renter-occupied housing units 2000	SF3, Table HCT3: Tenure by household size by units in structure (occupied housing units) SF1, Table H4: Tenure SF1, Table H1: Housing units	H4/H1
Transient/ Homeless	Homeless persons 2000*	SF1, Table QT-P12: Group quarters population by sex, age, and type of group quarters	

[1]The census contains many variables that can be used as indicators of broad characteristics associated with social vulnerability, as well as indicators of particular characteristics applicable to specific situations (e.g., detailed reporting on minorities, languages spoken, etc.). For details on census variables, consult census technical documentation reports (U.S. Department of Commerce 2007a, b).

*Total count of persons living in homeless shelters on a designated night (March 27, 2000); people receiving free meals at soup kitchens at a designated time on March 28, 2000; and people found living at designated street locations on March 29, 2000.

the profile data have been assembled, they can be summarized using basic percentages and proportions to compare and contrast areas (e.g., tract A has twice as many persons living below the poverty level as tract B, etc.). Information can also be presented using z-scores to identify areas (i.e., tracts, block groups) possessing characteristics associated with higher levels of vulnerability.[1] Computational procedures for creating a SVP are presented in Appendix D.

The NOAA Coastal Services Center's Risk and Vulnerability Tool (RVAT) (http://www.csc.noaa.gov/digitalcoast/training/roadmap/index.html) provides an online primer on conducting Social Vulnerability Profiling analysis (Figure 8). Additionally, FEMA's Emergency Management Institute provides a training program in understanding and using Social Vulnerability Profiling analyses (http://training.fema.gov/emiweb/edu/sovul.asp).

[1] More detailed directions and guidance for conducting social profiles can be found in Dunning and Durden (2009) and University of Illinois (2006).

Figure 8. NOAA Coastal Services Center on-line Social Vulnerability Profiling primer.

4.4 Example: Applying Social Vulnerability Analysis

This example applies the SoVI and SVP methods to census tracts in Chatham County, GA. The example does not refer to an actual, current or past Corps project; it is only intended to illustrate how a Social Vulnerability Analysis might be conducted on a unit of geography in relation to Corps planning process steps.

4.4.1 Chatham County Overview

Chatham County is located on the far eastern tip of Georgia and is the northernmost coastal county in the state. The county has a total area of 632 square miles, of which 438 square miles are land and 194 square miles are water. It is bounded on its northeast side by the Savannah River (Figure 9).

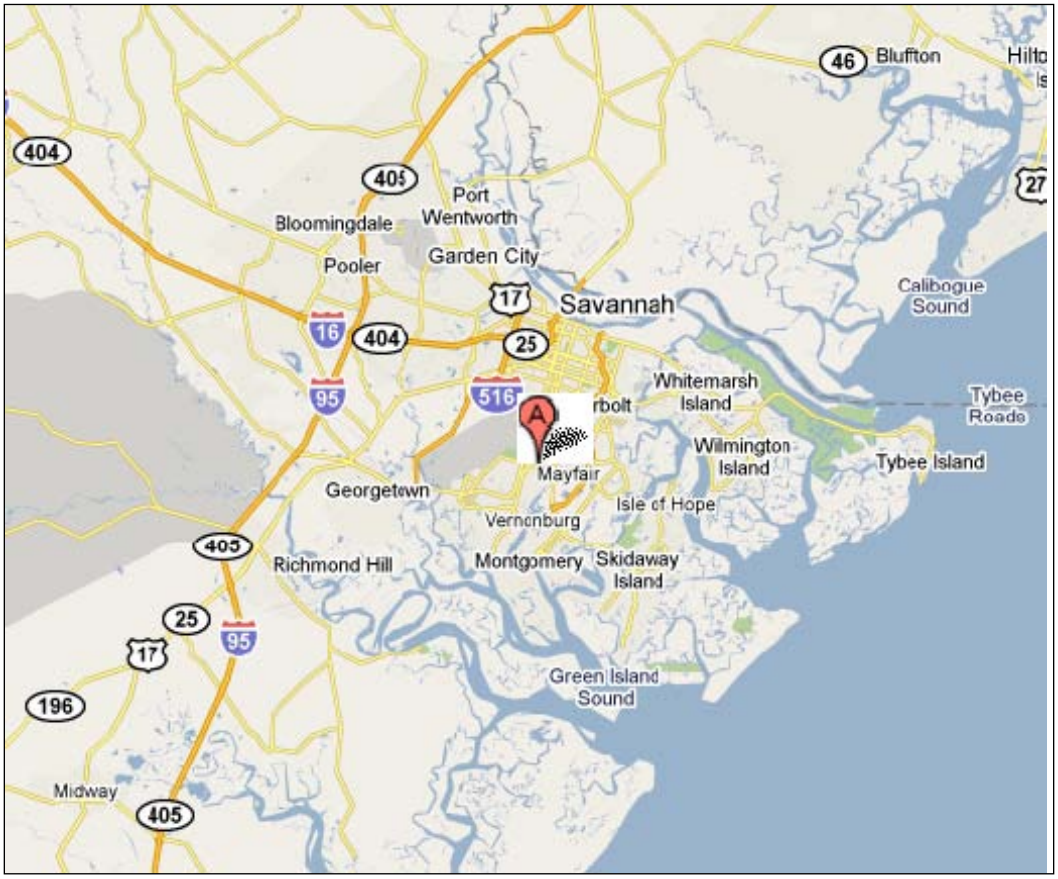

Figure 9. Chatham County, GA, and vicinity. (From Google Maps).

The U.S. Census Bureau estimates (2009) indicate that the population is 251,120. There are eight municipalities within Chatham County, GA: Bloomingdale, Garden City, Pooler, Port Wentworth, Savannah, Thunderbolt, Tybee Island, and Vernonburg. The City of Savannah is the county seat. Unincorporated areas such as Georgetown, Isle of Hope, Montgomery, Skidaway Island, Whitemarsh Island, and Wilmington Island are part of Chatham County's geography. Chatham County is part of the Savannah Metropolitan Statistical Area. The U.S. Census Bureau lists 68 census tracts in Chatham County and provides data for 67 of them (the tract omitted is an industrial area with no households) (Figure 10).

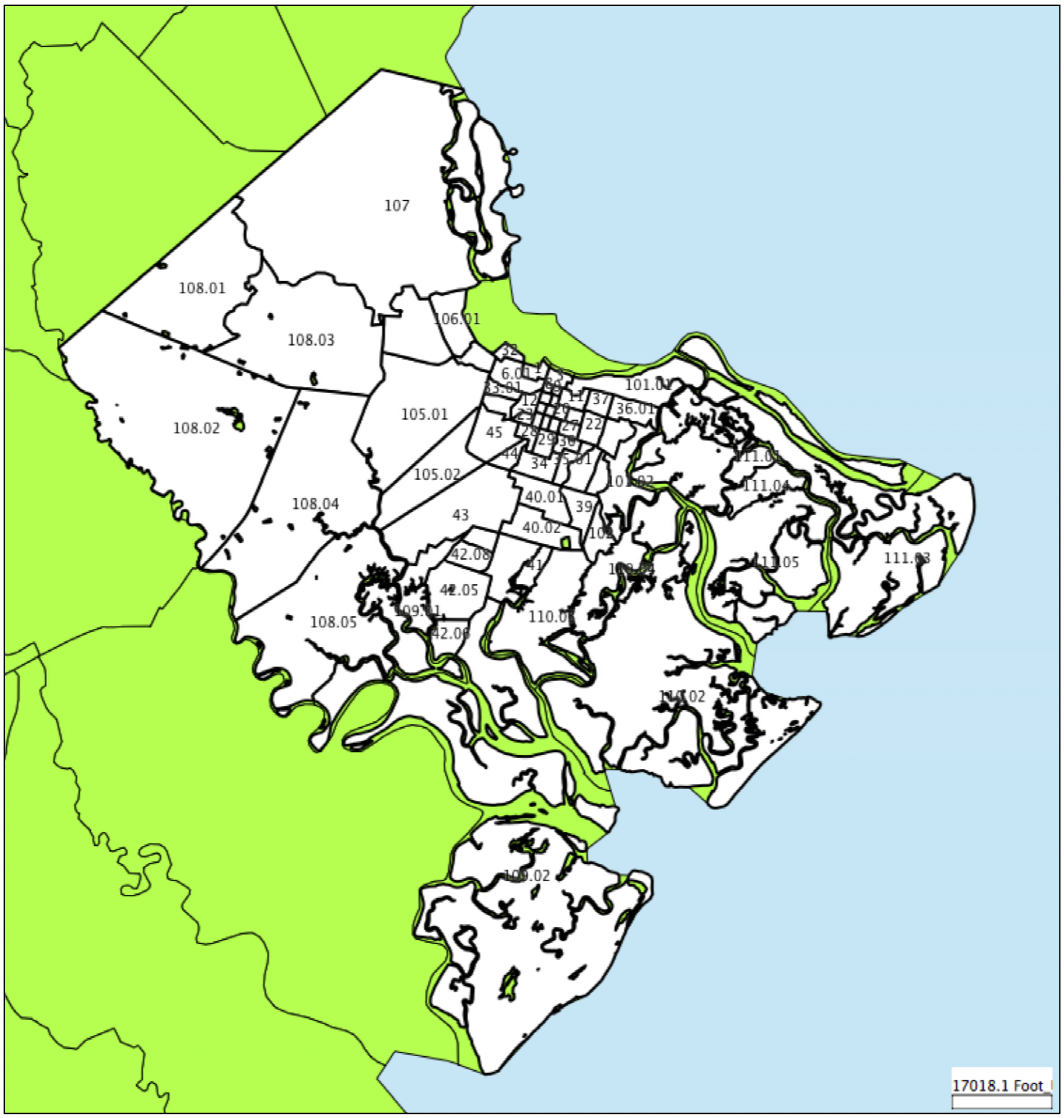

Figure 10. Chatham County, GA, census tracts.

Flood zone designations for Chatham County obtained from Digital Flood Insurance Rate Maps (DFIRM) were overlaid on census tract maps and colorized to highlight differences in flood zone designations across the county (Koch 2009). By visual inspection, 27 census tracts substantially covered by the 1 percent and 2 percent flood zones were selected to serve as the area of interest for applying the social vulnerability identification methods. These tracts are highlighted in Figure 11 and for further reference in this example will be identified as the *study area* to correspond with the term that could be used in a typical Corps report. In the 2000 census, 123,756 persons were listed as residing in the study area. The tracts outlined in blue in Figure 11 are characterized as "study area tracts"

and are located in areas of high physical risk to flooding, therefore making a detailed "place vulnerability analysis" irrelevant.

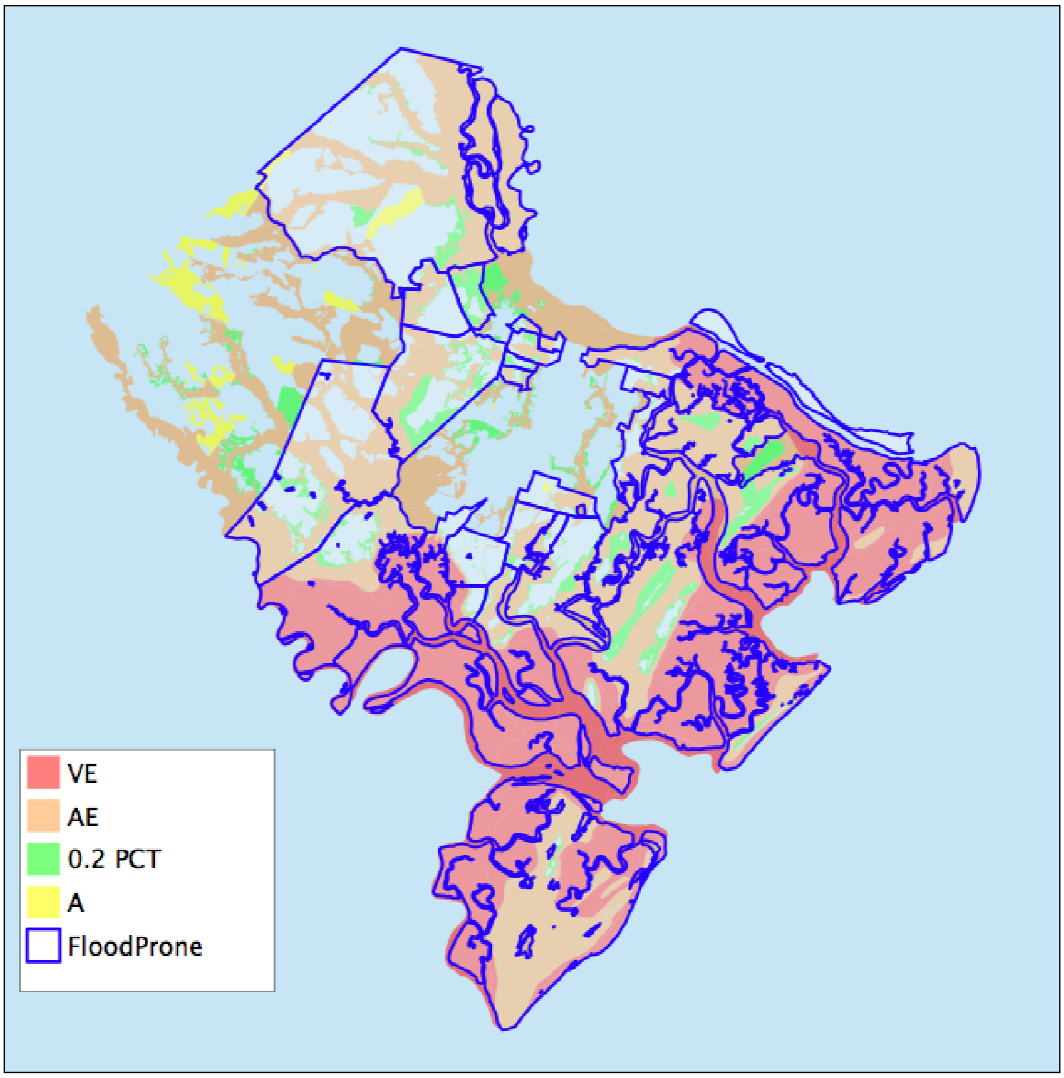

Figure 11. Chatham County census tracts substantially covered by flood zones and designated as "study area" tracts. The abbreviations are defined as follows: VE — high-risk coastal area with 1 percent annual chance of flooding with additional hazard of storm waves; AE — high-risk flood area with 1 percent annual chance of flooding; 0.2 PCT — areas with a 0.2 percent annual chance of flooding (also known as 500-year flood zone); A — high-risk flood area but historical information on flood heights is not available; "Flood Prone" — general description of areas most likely to experience flooding. For further information, see FEMA: http://www.msc.fema.gov/webapp/wcs/stores/servlet/info?storeId=10001&catalogId=10001&langId=-1&content=floodZones&title=FEMA%20Flood%20Zone%20Designations

4.4.2 Application of SVA Methods

SoVI. The procedures described in Appendix B were used to compute the SoVI for Chatham County census tracts; the results are shown in Figure 12.

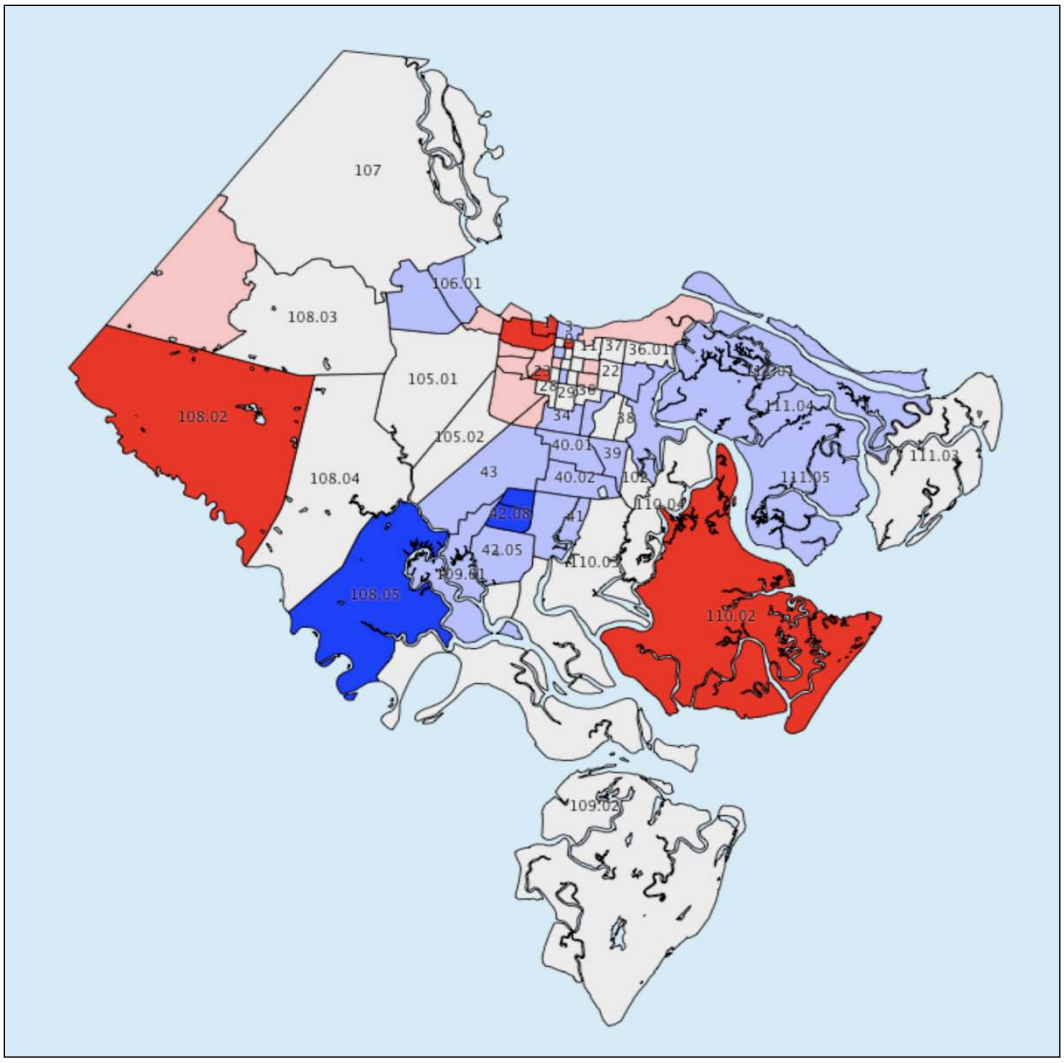

Figure 12. Chatham County, GA, census tract distribution of SoVI Scores. Pink indicates z-scores of 0.5–1.5 (moderate social vulnerability); red indicates z-scores of >1.5 (high social vulnerability).

Table 8 shows the 27 study area census tracts, noting those tracts in the upper ends of the distribution on the various social vulnerability dimensions. Examining the scores on the particular dimensions comprising the total SoVI score can yield important insights into determinants of vulnerability in census tracts. For example, in Table 8, eight tracts have a high factor score on an *Elderly* dimension comprising census variables *percent of population 65 or over*, *percent of population*

Table 8. Full SoVI showing drivers of vulnerability for Chatham County study area census tracts.

Census tract	Popula-tion	Race and class	Elderly	Housing tenure	Gender	Urban/ rural	Unemployed-female- headed households	Hospitals	Extractive industry	SoVI score
1	1215					X	X	X	X	X
6.01	4034	X	X			X			X	X
32	1111	X	X	X			X			X
33.01	1995	X	X	X	X	X				X
33.02	1851	X	X	X	X					X
36.01	3000	X		X		X				
40.02	3891							X	X	
41	2066			X						
42.02	8312					X			X	
42.05	9888			X				X		
42.06	1693			X	X					
101.01	2084	X		X			X			X
101.02	3738							X		
105.01	4720	X				X			X	
106.01	5685									
106.03	1848									
107	4484	X	X	X		X				
108.04	8331			X		X			X	
108.05	9241									
109.01	3652									
109.02	1170				X					
110.02	6958		X	X			X			X
110.03	6161			X	X				X	
110.04	3767		X	X	X					
111.01	7952									
111.03	3696		X							
111.05	9325			X	X					
TOTAL	123756									

Note: An X in a cell indicates that the SoVI score was at least ≥0.5, indicating higher levels of social vulnerability for the dimension or total SoVI score.

collecting social security benefits, and *median age*, while eight tracts (some of them the same, some different from those with high-elderly populations) have high scores on a *Race and Class* dimension comprising variables *percent living below poverty level*, *percent African American*, and *percent female-headed households*. Finally, seven tracts have a summed social vulnerability score that identifies them as being highly

socially vulnerable areas. See Chapter 5 for further discussion of application of this information in the planning process.

Social Vulnerability Profile. Another way of identifying social vulnerability in the study area census tracts is to perform a Social Vulnerability Profile (SVP) using the variables in Table 7.[1] Appendix D describes the procedures for computing each variable. Table 9 identifies study area census tracts that had higher proportions of characteristics that are associated with greater social vulnerability. For example, tract 1 (also indicated by the SoVI as a high-vulnerability tract) displays high proportions of poverty, persons under 5 years of age, disabled persons, female-headed households, non-English-speaking households, renters, and homeless. Tract 6.01 (also indicated by the SoVI) displays high proportions of poverty and persons 65 years of age or older, as well as persons under 5 years of age, disabled persons, and female-headed households. By inspecting the columns of social vulnerability indicators, it is also possible to gain an appreciation for the most frequently appearing drivers of vulnerability in the study area, as well as their spatial distribution. For example, the presence of high proportions of persons 65 years of age or older as well as the very young (those under 5 years of age) appears to be the most frequently appearing social vulnerability issue in the study area census tracts, followed by high proportions of mobile homes, the presence of non-English-speaking populations, and persons with disabilities.

It is also possible to graphically display the distribution of social profile variables across census tracts or other geography, much like was shown using SoVI scores. For example, Figure 13 presents the distribution of the profile variable *Percent of population aged 65 and over* across Chatham County census tracts.

[1] Once again it should be emphasized that the choice of potential profile variables need not be limited to those shown in Table 7 but can be widened or narrowed to focus on social vulnerability characteristics that may be appropriate to the particular area.

Table 9. Study area census tracts showing high social vulnerability and drivers of vulnerability as indicated by Social Vulnerability Profiling Method.

Census tracts	Popula-tion	Low income/ poverty	Age: elderly/ young	Disabled	Female households	Minorities (nativity)	Mobile homes	Renters	Homeless
1	1215	X	X	X	X	X		X	X
6.01	4034	X	X X	X	X				
32	1111			X					
33.01	1995		X	X					
33.02	1851		X			x			
36.01	3000		X						
40.02	3891		X						
41	2066					X			
42.02	8312							X	
42.05	9888								
42.06	1693		X						
101.01	2084	X	X		X	X			
101.02	3738						X		
105.01	4720			X			X		
106.01	5685		X				X		
106.03	1848							X	
107	4484						X		
108.04	8331		X				X		
108.05	9241		X						
109.01	3652						X		
109.02	1170					X			
110.02	6958		X				X		
110.03	6161								X
110.04	3767					X			
111.01	7952								
111.03	3696		X						
111.05	9325								
TOTAL	123756								

Note: An "X" in a cell indicates that the z-score for the social vulnerability characteristic was at least ≥0.5, indicating higher levels of social vulnerability for the characteristic.

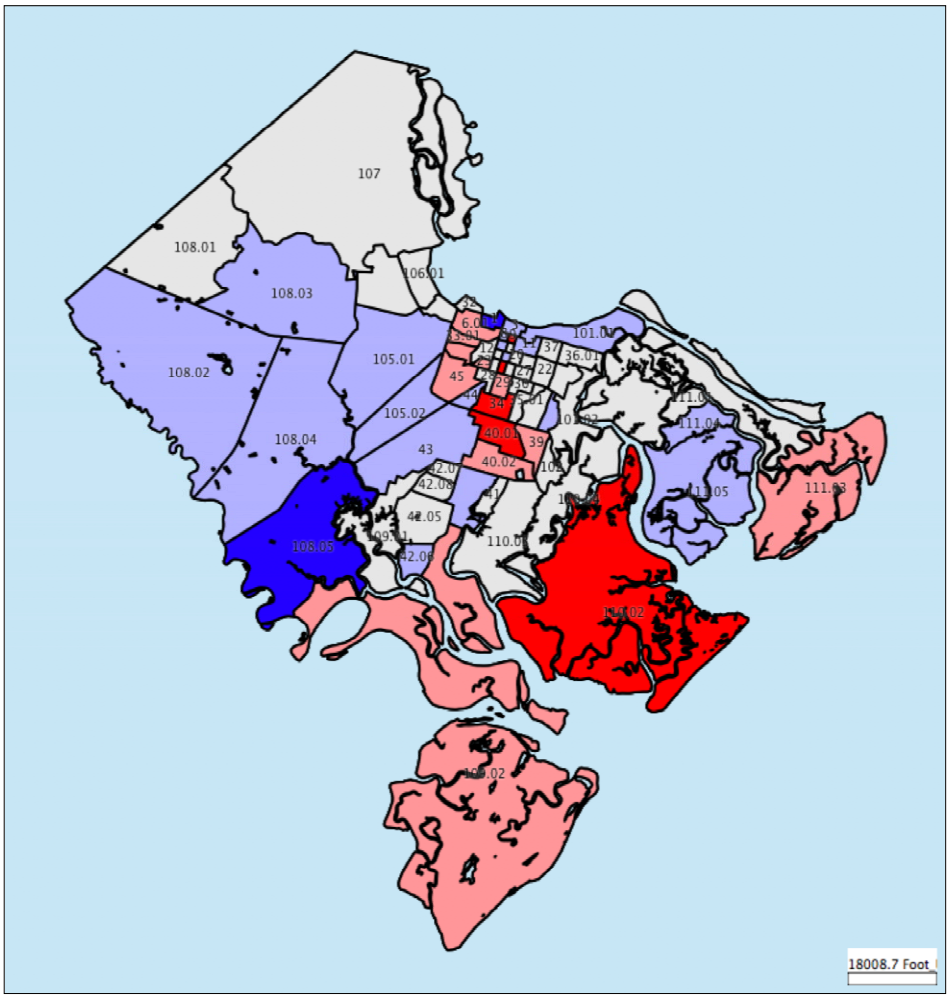

Figure 13. Percent of population aged 65 or over, Chatham County, GA, census tracts. Pink indicates z-scores of 0.5–1.5 (moderate social vulnerability); red indicates z-scores of >1.5 (high social vulnerability).

Comparing and Contrasting SoVI and SVP. One should be cautious when comparing and interpreting the results of a SVP to those of a SoVI. As illustrated by the results in Tables 8 and 9, the two approaches may provide different information about vulnerability based on the analysis process and variables included in the profile.

Unlike the SoVI, a Vulnerability Social Profile does not follow a prescribed set of variables and procedures. Rather, the profile is custom made for each application and therefore may be open to charges of bias in what was included or excluded from the analysis. When examining the results in Table 8 and Table 9, one can see how the choice of variables and the process of creating principal components from several variables may result

in different insights and perspectives on the vulnerabilities. The evaluation of similar, though not identical variables, results in findings that may be interpreted differently.

The choice of "parent area" is another important consideration when developing a SoVI or SVP. Vulnerability of an area of interest is statistically described in relation to the vulnerability characteristics of a larger geographic area (the parent area). Choosing an appropriate area of interest that provides observable variation in the variables of interest allows for a more relevant analysis. Users of both the SoVI and the SVP should consider selecting a parent area large enough to produce meaningful relative values in the distribution of vulnerability characteristics.

4.5 Applicability of Social Vulnerability Analysis Methods for Corps Planning

The SoVI and SVP methods are useful for identifying socially vulnerable populations, and both can productively be used in Corps planning applications. However, each method has strengths and weaknesses that should be recognized.

The SoVI is widely used and cited in hazard research and management. The University of South Carolina's Hazards and Vulnerability Research Institute (HVRI) maintains a SoVI website (http://webra.cas.sc.edu/hvri/products/sovi.aspx) that provides information on the index and where it is being used. Numerous academic articles have been published on SoVI analyses, providing a substantial degree of peer review. The method helps focus attention on critical social vulnerability issues and by so doing can better ensure that such concerns are addressed in the planning process. The information on drivers of social vulnerability provided by the SoVI dimensions can be particularly useful in identifying factors that may need to be addressed in FRM planning. While the SoVI computation can be somewhat daunting, the HVRI offers assistance and consultation. Because of its wide use, the SoVI results can be compared and contrasted with other cases to focus on issues of key drivers of vulnerability and changes in vulnerability over time.

The SoVI, however, does present some challenges for use in a public planning context. First, the method is complex and uses a statistical procedure that is not easily communicated to a nonspecialized audience. Additionally, the relative nature of the SoVI's values can be difficult to appreciate, and results can be misinterpreted or misrepresented.[1] Members of the public may expect definitive answers about social vulnerability issues and might be less satisfied with answers that have to be couched as comparisons among areas.

The SVP method provides a simple and direct method of focusing on vulnerability characteristics in a study area. With web-based census tools, it is relatively easy to assemble the necessary information and create the profiles. The vulnerability information is also likely to be somewhat easier to present and explain in a public forum in that only simple tabulations of information are required. The SVP may be more suitable for reconnaissance-level examinations of a study area while SoVI applications requiring more time and effort may be more suitable for survey-scale applications.

Regardless of whether the SoVI or a SVP approach is used in a planning context, caution must be exercised in the interpretation and use of the information on at least two accounts. First, the data may be at geographic scales that are too coarse for detailed analyses. Second, there may be problems in interpreting social vulnerability information obtained from the methods.

Problems with Data. The Social Vulnerability Analysis methods use census information compiled for the most part from the most recent census. Social conditions in an area may have changed through redevelopment, gentrification, etc., since the most recent census and may provide an inaccurate picture of the current situation. Where possible,

[1] See, for example, the *Washington Post* article of April 5, 2008, "Terrorism Study Drops a Bomb on Boise" (Layton and Surdin 2008), which notes, somewhat tongue-in-cheek, that a vulnerability study using the SoVI had concluded that Boise, Idaho, had ranked first among 132 American cities as most vulnerable in the event of a terrorist attack: "Quick: Name the Western U.S. city most vulnerable to a terrorist attack. Is it Los Angeles, with its crowded roads that make quick escape impossible? San Francisco and its iconic bridge? Or Seattle with its Space Needle and busy port? Try Boise, Idaho, with its, um, potatoes." The article included quotes that suggest that the research was suspect, since it placed targets such as San Francisco and Los Angeles further down the list. The researchers at HVRI responded by noting that the SoVI examines those pre-existing and past conditions/characteristics of people and places that influence an urban area's potential for harm from hazards and its ability to recover from hazards and that it was inappropriate to confuse threat and vulnerability.

updated census estimates for variables should be used,[1] and additional GIS-based information such as locations of nursing homes, homeless shelters, welfare caseloads, etc., that may be useful indicators of the location of socially vulnerable groups can also be sought out.

Interpreting Social Vulnerability Information. The meaning and significance of indicators of potential social vulnerability should not be considered self-evident. For example, the identification of several census tracts having a large proportion of poor immigrant residents in a flood zone should trigger potential concerns about possible impacts should a hazard event occur. However, these findings are only indicators of the possible presence of social vulnerability issues that may be important to consider in the planning process. They should be treated as flags that point toward the need to determine whether and to what extent particular social vulnerability issues affect how hazard conditions need to be addressed.

The way that the meaning and implications of such issues are established is through an iterative process of analysis, drawing tentative conclusions, consulting with local interests, and engaging with those interests to discuss the importance and implications of the information and its relevance to planning issues (Figure 14).

[1] For example, the census provides annual estimates of total population and number of families in poverty with children aged 5–17 by county and school district to support the "No children left behind" law [see Census Small Area Income and Poverty Estimates (SAIPE) program (http://www.census.gov//did/www/saipe/)].

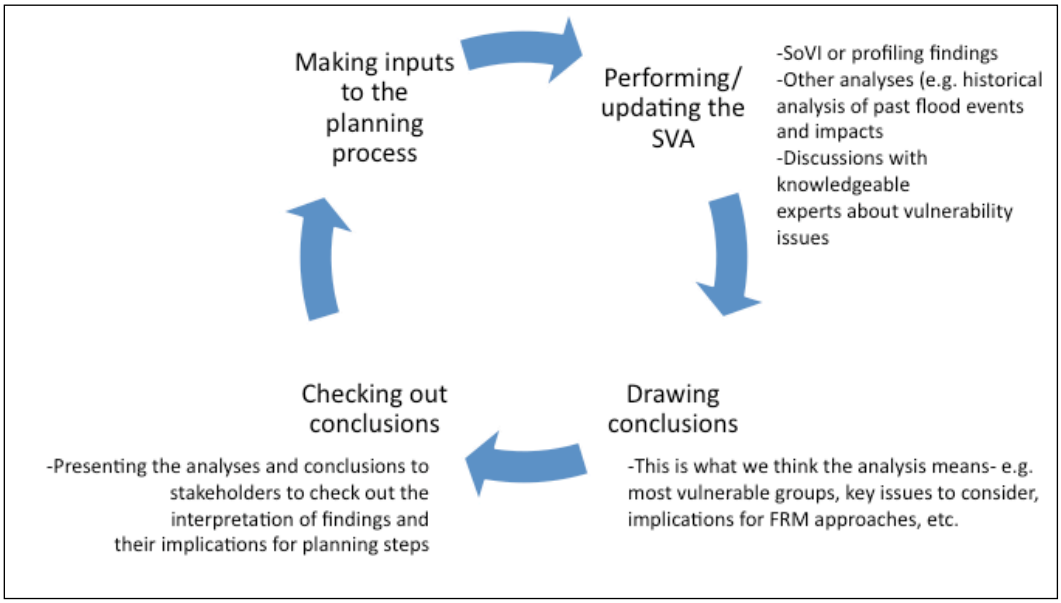

Figure 14. Establishing the meaning of social vulnerability information.

4.6 Section Wrap-up and Look Ahead

The SoVI and the SVP are both census-based methods for identifying socially vulnerable groups. The SoVI is widely used and cited; however, it is the more difficult method to construct and may present difficulties of explanation and interpretation in a public planning setting. The SVP method also requires care and attention in construction but is likely to be more easily understood. A limitation of both methods is their reliance on census data, which, as time passes from the time of collection, may be increasingly inaccurate. It is also important to recognize that information produced by either method does not speak for itself. Rather, its meaning and significance is best established through an iterative process of analysis and consultation. The next section continues the example of the Chatham County, GA, study area to consider how social vulnerability information can be used in the Corps planning process.

5 Applying Social Vulnerability Information in the Corps Planning Process

Using the SoVI and the SVP results for the Chatham County study area, this section now considers how information about social vulnerability characteristics might be used in the Corps' six-step planning process.[1] The section presents and elaborates on the steps presented earlier in Table 5. Each step in the planning process is shown below, together with a number of key questions that SVA can help address.

5.1 Planning Process Steps

5.1.1 Step 1: Specify Problems and Opportunities

- **Questions:** What groups are especially vulnerable? Where are they located? What are the water-resources-related needs and interests of vulnerable groups?
- **Answer:** SVA can help identify areas within the study area that have high concentrations of socially vulnerable populations and can alert the planning team to the kind of special needs that the presence of such populations present. Once such groups have been identified, other tools, such as interviews and workshops, can be used to gain a better understanding of the concerns and needs of such groups.

The first step in the planning process is focused on gaining a good understanding of the water and related land resources problems and issues, identifying constraints and opportunities, and defining planning objectives. SVA, as a component of a broader social effects analysis, can help the study team gain a better understanding of the social landscape and help provide insights about locations within the study area with greater concentrations of socially vulnerable populations. Such information can serve as a red flag to call attention to the need to engage with vulnerable groups to obtain more detailed information about special needs and issues that may need to be factored into the planning process.

[1] For a full explanation of the steps in the planning process, see Orth and Yoe (1997), and as applied more specifically to the use of Other Social Effects information in the planning process, see Dunning and Durden (2009).

For example, Table 10 shows the results of applying the SVP method to the Chatham County study area, showing where socially vulnerable groups are concentrated and summarizing the special needs that such groups may have. The SVA method suggests that special attention should be paid to census tracts 1, 6.01, 32, 33.01, 33.02, 101.01, and 110.02 because they have high concentrations of socially vulnerable populations. Additionally, the analyses suggest that key drivers of vulnerability in the study area are likely to be the presence of older as well as younger residents, mobile homes, non-English-speaking minorities, and persons with disabilities. Table 10 suggests the kinds of concerns that vulnerable groups are likely to have and the kinds of needs that are likely to be important planning considerations. Special attention needs to be paid to ensuring that stakeholders representative of these specific census tracts and social characteristics are engaged so that the problems, needs, and views of these groups are included in the problem- and need-identification process.

Table 10. Flood impacts on vulnerable populations.

Vulnerability factor	During event	Recovery	Study area tracts with high vulnerability in factor*
Low income/ poverty level	Lack of resources may complicate evacuation	Lack of resources may hinder ability to recover	1, 6.01, 101.01
Age (elderly/ young)	Greater difficulties in evacuation, more health and safety issues, potential for higher loss of life	May lack resources, willingness, ability to rebound	1, 6.01, 33.01, 33.02, 36.01, 40.02, 42.06, 101.01, 106.01, 108.04, 108.05, 110.02, 111.03
Disabled	Greater difficulties in evacuation, special health and safety issues, potential for higher loss of life	May lack facilities and medical personnel to provide care	1, 6.01, 32, 33.01, 105.01
Female-headed households	Lack of resources and special needs may complicate evacuation	Lack of resources may hinder ability to recover	1, 6.01, 101.01
Minorities	Lack of influence Language difficulties	Lack of influence Language difficulties	1, 33.02, 41, 101.01, 109.02, 110.04
Occupants of mobile homes/ renters	Occupy more vulnerable housing	Potential displacement with higher rents	101.02,105.01, 106.01, 107, 108.04, 109.01, 110.02
Transient/ homeless	Difficult to locate and provide information to; difficult to estimate numbers		1, 110.03

* As indicated using the Social Vulnerability Profiling method.

5.1.2 Step 2: Inventory and Forecast Conditions

- **Questions:** What is the current risk, in general and to vulnerable groups? What are likely impacts of events of various magnitudes, with special focus on vulnerable groups? How well is risk understood?
- **Answer:** SVA can help build understanding about the risks associated with the future without project condition. The analysis can point out specific examples and instances that are possible in the future.

This step in the planning process is concerned with describing and understanding current and future social conditions of concern to stakeholders in the absence of a water resources solution. The focus of the analysis includes identifying the likely impacts of flood events of various magnitudes on vulnerable groups in the study area if a proposed project were not undertaken, as well as considering the presence and significance of potential resilience factors[1] that may mitigate negative impacts of flooding and/or recovery. For example, the Chatham County SVA shows that 735 persons out of the 4,034 residents in tract 6.01 are 65 years of age or older (18 percent) and that 502 of the 735 (68 percent) have disabilities. Using such insights, planners should explore questions such as the following: In a future flood situation, what resources would be required to evacuate this group of residents? Does this group of residents understand the risks associated with living in a flood-prone area? How can elements describing current risk—threat, vulnerability, and consequences—for this group be most effectively communicated? What special circumstances need to be taken into account to assist in facilitating public understanding of risk issues?

Social Factors in Communicating Risk and Uncertainty

The interpretation and meaning of both risk and uncertainty in decision making depend on people's knowledge and perceptions. For example, concepts such as level of protection, 100-year floodplain, or 100-year flood are commonly used when discussing flood damage reduction strategies. Such terms are easily misunderstood by the public and need considerable clarification if a reasoned discussion about flood damage reduction alternatives is to take place. A more detailed knowledge of the composition

[1] A resilience assessment using a procedure like that shown in Table 3 would likely be a part of this planning phase.

of groups occupying the study area can help in tailoring more effective communication strategies for discussions about risk issues.

Additionally, risk tolerance among the population may be influenced by many factors (see Table 11), including social factors that influence vulnerability and resiliency as well as the trust that the public has in the source of the information (U.S. Department of Health and Human Services 2002).

Table 11. Factors affecting acceptability of risks. (From U.S. Department of Health and Human Services 2002).

Risks Perceived to...	Are More Accepted Than Risks Perceived as...
Be voluntary	Being imposed
Be under an individual's control	Being controlled by others
Have clear benefits	Having few benefits
Be distributed fairly	Being unfairly distributed
Be natural	Being man-made
Be statistical	Being catastrophic
Be generated by a trusted source	Being from an untrusted source
Be familiar	Being exotic
Affect adults	Affecting children

Public input should also be required to help determine how the acceptability of risk is judged, what trade-offs exist between acceptable levels of risk and residual risk, and how to design strategies for coping with remaining levels of risk and uncertainties (Renn 1998, Macgill and Siu 2005), and once again improved knowledge of social characteristics of those living in the study area can help shape more effective and inclusive communication strategies.

5.1.3 Step 3: Formulate Alternatives

- **Question:** What kind of measures can best address the needs and interests of vulnerable groups?
- **Answer:** In addition to the traditional structural solutions to flood problems, a range of nonstructural measures such as improving warning systems and evacuation procedures, increasing participation in flood insurance, defining roles and collaborating with community organizations, and building community social capital should be explored.

The process of formulating alternatives focuses on intervening in the defined situation to alter the future in ways that better address planning objectives. Table 12 shows typical concerns that vulnerable groups have that might be part of the results of Steps 1 and 2 of a planning process. As discussed previously for the Chatham County study area, special attention might be placed on engaging with residents in the several high-social-vulnerability census tracts as well as more generally with stakeholders representative of the vulnerability characteristics that are most common in the study area, such as agencies providing services to the disabled or elderly, to discuss potential options for addressing concerns.

Table 12. Example FRM concerns and needs.

Vulnerability factor	Concerns and needs during event	Concerns and needs during recovery
Low income/ poverty level	Efficient, effective notification	Assistance in coping with economic and social problems in aftermath Help with clean-up, dealing with insurance and other bureaucracies
Elderly	Efficient, effective notification Quick, efficient evacuation (knowing what to take, where to go, how to get there, getting someone to help) Protecting homes from looting	Assistance in getting back into residence Help with clean-up, dealing with insurance and other bureaucracies
Disabled	Quick, efficient evacuation Evacuation centers with medical support.	Availability of usual support services.
Female-headed households	Quick, efficient evacuation Child-friendly evacuation centers	Assistance in coping with economic and social problems in aftermath
Minorities	Receiving communications in language the minority understands Receiving communications from a trusted source	Obtaining access to redevelopment funds for minority/ethnic neighborhoods
Occupants of mobile homes/ renters	Efficient, effective notification	Assistance in coping with economic and social problems in aftermath
Transient/ homeless	Efficient, effective evacuation	

The emerging FRM approach is envisioned to move beyond the traditional concern with developing a purely structural solution to flood problems. Instead, it is likely that a combination of structural and nonstructural solutions representing the authority of several agencies may make up one or more FRM plans being evaluated (Figure 15).

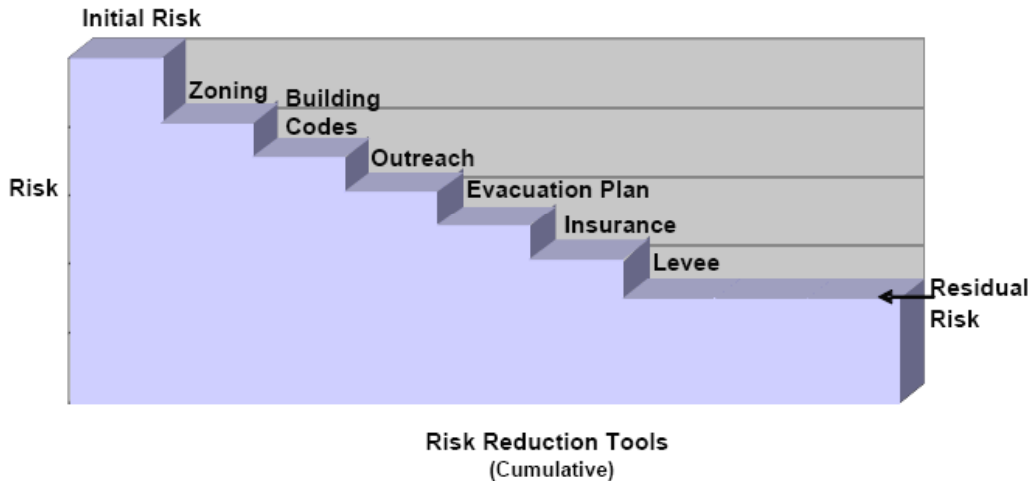

Figure 15. Flood risk management: A combination of many approaches. (From Riley 2008.)

The needs and concerns of vulnerable populations can help identify the measures that should be developed and combined into complete, effective, efficient, and acceptable plans. While analysis is helpful, it is best used as input for interacting with vulnerable populations themselves, or with their surrogates, to obtain their input about potential measures.

5.1.4 Steps 4, 5, and 6: Evaluating, Comparing, and Selecting Plans

- **Question:** What is the distribution of risk? Who is most at risk? What are the social impacts? How do plans compare with respect to completeness, effectiveness, efficiency, and acceptability?
- **Answer:** Plans can be compared on their residual risk and effects on socially vulnerable populations. Such comparisons can help crystallize the choices that plans offer.

Social vulnerability analysis should help communicate alternate plans' social effects in ways that illuminate the choices various plans constitute for vulnerable groups. A first step is describing or characterizing plans' effects on vulnerable groups in terms of descriptors such as magnitude—the numbers of people or groups affected; location—where the effects are likely to occur; timing and duration—when effects will start, how long they will last; and risks associated with the plan.

- **Completeness**: Does the plan address the water resource problem, including concerns and needs expressed by vulnerable groups?
- **Effectiveness**: How well does the plan address the water resource problems and opportunities?

- **Efficiency**: Does the plan address the water resource problem in a cost-effective way?
- **Acceptability**: Does the solution achieve a tolerable level of risk? Is the solution acceptable to the communities, including vulnerable groups?

Table 13 shows how factors addressing risk and effects on socially vulnerable populations might be compared for competing plans to help illuminate choices and facilitate discussions among stakeholders. Three plans are shown, with different levels of protection, amenities, and effects on socially vulnerable populations. It can be seen that the inclusion of residual risk associated with plans highlights the issue that risk remains for events that exceed the structural level of protection being provided and necessitates confronting the question: What then? It is likely that complete plans will explicitly include an ensemble of nonstructional institutional and organizational measures to address such concerns. The existence of a plan that provides no structural protection to a neighborhood disproportionately populated by socially vulnerable residents (see Assumptions below table) can help focus attention on such issues and can lead to a more complete assessment of plans' adequacy.

5.2 Section Wrap-up and Look Ahead

This section has focused on applying Social Vulnerability Analysis in the Corps planning process. Social Vulnerability Analysis methods can help identify locations with high concentrations of special needs populations. The particular vulnerability characteristics identified may raise particular issues for planning; for example, the presence of a large immigrant population in a location may necessitate special communication requirements. The explicit inclusion of residual risk into formulation will emphasize the need for creating plans that address coping with events that exceed the design level of structural protection. Nonstructural measures that can explicitly address issues and needs of socially vulnerable populations will likely be part of the ensemble of measures beyond purely structural flood damage reduction measures that will be included in plans. Displaying the distribution of plan effects on socially vulnerable populations may help focus attention on issues of plan completeness and effectiveness. The final section provides concluding comments on the applicability of Social Vulnerability Analysis to Corps planning and its potential role in other Corps programs, and it speculates on ways that Social Vulnerability Analysis might be further improved.

Table 13. Illustrative characterization of plans' effects.

Current Risk	**0.2% Chance**		**1% Chance**
Population at risk for flooding • Elderly • Very young • Poor • Disabled	89,060 12,395 6,520 11,200 16,478		55,663 7,747 4,075 7,000 10,299
Residual risk	**Plan A**	**Plan B**	**Plan C**
Population at risk for flooding *0.2% Chance* • Elderly • Very young • Poor • Disabled *1% Chance* • Elderly • Very young • Poor • Disabled	 89,060 12,395 6,520 11,200 16,478 5,010 775 408 700 1030	 89,060 12,395 6,520 11,200 16,478 0 0 0 0 0	 89,060 12,395 6,520 11,200 16,478 16,699 3,874 1,223 4,200 5,150
Relocations			
Number to be relocated	1,000	700	500
Businesses to be relocated	30	3	30
Location			
% of 1% floodplain protected in: • CBD • Neighborhood A • Neighborhood B • Neighborhood C	 100 90 90 90	 100 100 100 100	 100 0 100 100
Disruptive effects of plan localized in:	CBD	Few	Neighborhood A
Timing and duration			
Time before flood protection provided	8-10 yr	10-12 yr	5-7 yr
Duration of construction	4 yr	6 yr	3 yr
Effects on soc. vuln. groups			
Elderly	Targeted warnings and evacuation assistance provided	Targeted warnings and evacuation assistance provided	50% of elderly located in Neighborhood A Targeted warnings and evacuation assistance provided
Poor			Neighborhood A is primarily lower income and is not afforded structural protection
Disabled	Special evacuation assistance	Special evacuation assistance	50% of disabled live in Neighborhood A Special evacuation assistance
Adequacy factor			
Completeness: Does plan address all social vulnerability issues of concern?	Yes	Yes	No, omits concern for viability of Neighborhood A
Effectiveness: How well does plan address social vulnerability issues of concern?	Some negative impacts	Addresses all issues well	Omits concern for viability of Neighborhood A
Efficiency: Does plan address social vulnerability issues of concern in cost-effective way?	Yes	Most expensive plan	Least expensive plan
Acceptability: Is proposed solution acceptable?	Yes	Yes	No, divides community into haves and have-nots; leaves Neighborhood A vulnerable

Table Assumptions:

1. Eighty percent of total population lives in 0.2 percent chance floodplain; 50 percent of total population lives in 1 percent chance floodplain.

2. These percentages apply to socially vulnerable populations as well.

3. Plans A, B, and C provide structural protection for 1 percent floods, but do not provide structural protection for 0.2 percent events.

4. Plan A provides structural protection for 90 percent of population for 1 percent events; same percentage applies to socially vulnerable populations.

5. Plan B provides structural protection for 100 percent of population for 1 percent events; same percentage applies to socially vulnerable populations.

6. Plan C excludes "Neighborhood A" from structural protection for 1 percent events (30 percent of the total population resides in Neighborhood A, 60 percent of the poor population, 50 percent of the elderly, and 50 percent of the disabled population reside in Neighborhood A) and provides structural protection for 70 percent of total population.

6 Conclusions

6.1 Role of Social Vulnerability Analysis Methods in Corps Planning

Social Vulnerability Analysis can enable a finer-grained understanding of social vulnerability factors that should be considered in planning. The SVA methods can assist in identifying the presence and general spatial distribution of socially vulnerable populations. The particular characteristics of such populations—age, poverty, minority status, etc.—have importance for the types of problems, needs, and opportunities that planning will confront and for the range of measures that will need to be considered in formulating complete, effective, efficient, and acceptable solutions.

6.2 Other Potential Applications for SVA

In addition to its use in FRM planning, SVA has direct relevance for emergency-management planning and operations. A more detailed understanding of a community's social vulnerability characteristics and spatial distribution can help emergency managers:

- Tailor messages to address language differences and engage in targeted trust-building to address populations that might be fearful of authority;
- Improve mobilization for evacuation to better address special needs populations such as the elderly, the very young, and the disabled; and
- Anticipate and plan for impact mitigation.

For example, in the aftermath of hurricanes, lower-income renters in coastal communities have sometimes been displaced by construction workers who have in-migrated to help in rebuilding (Goldstein 2009). By knowing the location of such socially vulnerable areas, it may be possible to work with local communities to create mitigation strategies in advance.

Social Vulnerability Analyses can also be applied to large-scale FRM scenario planning such as the Foresight[1] procedure to create broad comparisons of at-risk vulnerable populations under different scenarios and planning assumptions.

SVA may have relevance to the Corps' regulatory public interest review process as well (see 33 CFR 25). By providing the appropriate context for addressing the potential impacts of a proposed permit to socially and environmentally vulnerable populations, SVA can provide additional information pertinent to an evaluation of the permit action on the needs and welfare of the people.

Other tools currently under development such as LIFESim (estimate of lives at risk due to dam or levee breaks) and the Watershed Investment Decision Tool (a compilation of a wide range of factors influencing water resources) can incorporate the SOVI methodology to provide critical data on social vulnerability.

6.3 Improving Social Vulnerability Analysis

Both the SoVI and the SVP approach can help identify socially vulnerable populations, but both methods are currently limited by their reliance on census data. It is possible that the methods could be improved by incorporating non-census, small-area data. For example, Figure 16 shows the addition of vulnerability information (nursing home locations) contained in on-line mapping software. Figure 17 shows the storm surge information for Chatham County that has been exported into a Google Map framework. Integrating various layers of census, flood risk zones, storm surge zones, and small-area data on such Geoweb platforms shows great promise.

[1] Foresight (see http://www.nfrmp.us/presentations.cfm for information) is a structured framework that considers four science-based scenarios of socioeconomic development and climate change to "provide an indication of future risks from flooding and coastal erosion." It looks at the next 30 to 100 years, "quantifying the possible scale of the challenges that we face and providing a broad assessment of the different measures available to reduce risk."

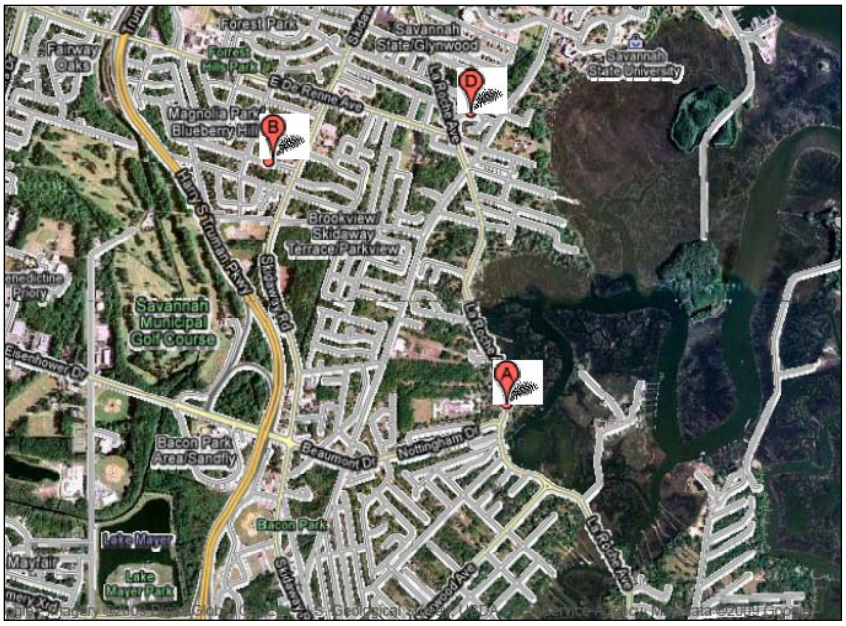

Figure 16. Portion of Chatham County, GA, showing nursing homes. (From Google Maps.)

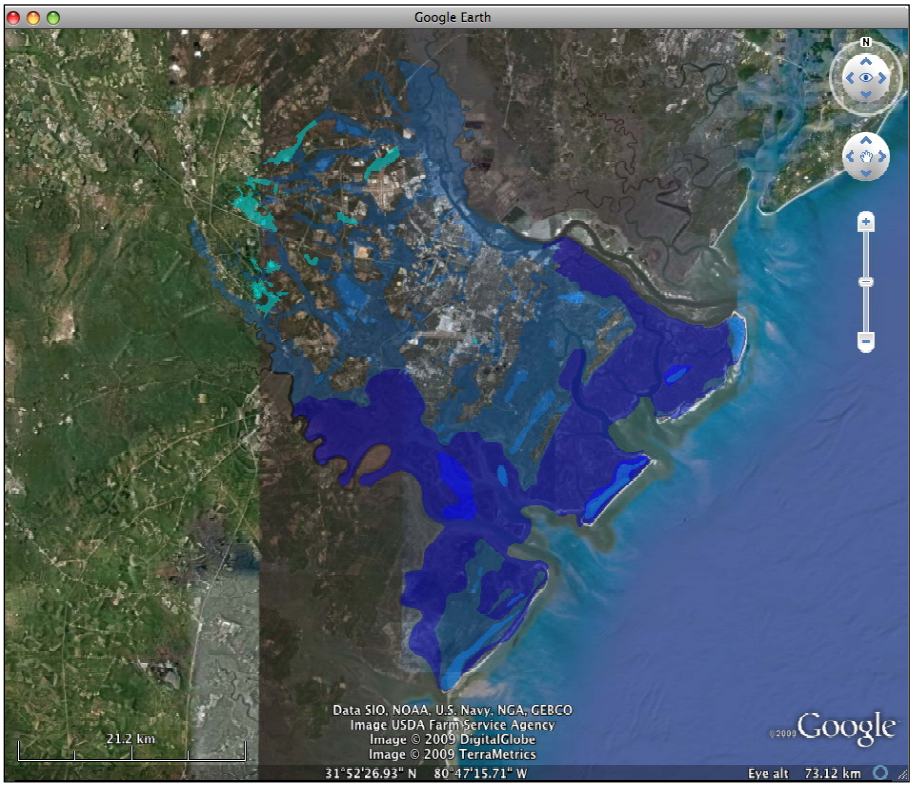

Figure 17. Overlay of storm surge zones onto a Google map of Chatham County, GA. (From Koch 2009.)

6.4 Summary

Information on socially vulnerable groups is critical to integrated, comprehensive flood risk planning. This report has outlined two methods to obtain this information and has illustrated its use in the planning process. The appendices that follow provide greater detail on performing the calculations to develop a Social Vulnerability Index and Social Vulnerability Profile.

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Appendix A: Common Tools for Addressing Social Vulnerability Issues

This appendix provides a quick overview of common tools that can be used in combination with SoVI or Vulnerability Social Profiling to support Social Vulnerability Analyses in the planning process. The descriptions are excerpted and slightly updated from Dunning and Durden (2009) (http://www.iwr.usace.army.mil/docs/iwrreports/09-R-4.pdf).

A1 Content Analysis

Content analysis is a structured method to systematically record the content of written material (e.g. letters to the editor, news articles, blogs, etc.) into meaningful categories of information that can then be analyzed using basic descriptive statistics and cross tabulations (Creighton and Dunning 1982). A detailed codebook is created that assigns codes to topics of interest, such as stakeholder groups, issues raised, intensity of feeling expressed,[1] as well as other pertinent information, such as date of issue, geographic areas mentioned, etc. The analyst would then systematically go through the written materials and record information, using the appropriate codes, into a spreadsheet.[2] When the data have been encoded, the analyst can perform analyses to answer questions such as: What are the most frequently mentioned issues of concern? How do issues of concern vary by stakeholder group? How have frequency, type, and intensity of issues varied over time?

[1] Qualitative variables such as intensity of feeling can be measured if the codebook provides indicators of what variable values mean—e.g., the presence of "value-laden" language or other expressions of emotion would be coded one way, while a simple recitation of facts or data would be coded in another.

[2] Researchers often have multiple persons perform the same coding and compare their results to ensure that the coding scheme is reliable—i.e., different people assign the code values the same way. Percent of coder agreement can be computed as a rough measure of intercoder reliability; however, more sophisticated measures are also available in standard statistical software packages such as the Statistical Package for the Social Sciences (for more information see http://www.temple.edu/sct/mmc/reliability/#How%20should%20researchers%20calculate%20intercoder%20reliability%20What%20software%20is%20available).

A2 Delphi Panels/Expert Panels

The Delphi method[1] is a technique for eliciting judgments from experts, typically by mail or email. It was originally developed by the RAND Corporation to produce technology forecasts. While often used as a forecasting tool, the Delphi method can be used to elicit group judgments on almost any topic (for example, coming to a group determination of an area's vulnerability, or the potential effectiveness of a FRM measure). A Delphi panel is typically composed of five to 12 persons selected for their knowledge and expertise in the topic area. Panel members do not meet together as a group and may not even know the identity of other panelists. During the panel sessions each person's input is kept anonymous so as to avoid undue influence based on reputation and also to permit members to change positions without loss of face.

A typical Delphi process has three rounds. Round 1 consists of posing the question and obtaining initial estimates. Panel members receive background information about the issue and are asked to provide a response to the Delphi question together with the rationale for their response. Panel moderators aggregate responses. If a quantitative response (e.g., a forecast) is the desired product, statistical summaries of the responses (means, medians, quartiles, etc.) to describe variation will be produced. This information is then fed back to the expert panel for their consideration. In Round 2 panelists are asked to review the results of Round 1 and revise their estimates based on the new information provided. Once again, panelists are asked to make an estimate and provide justification. Moderators again aggregate the information and feed it back to panelists with a request for any additional changes and justifications to estimates. Round 3 provides panelists with a final opportunity to make any changes to estimates.

In practice, Delphi estimates often converge to a central tendency. The method has detractors who note that it can be biased by the way questions are posed and by the choice of experts. However, studies have also shown that the method has generated forecasts superior to those obtained by other methods.

[1] Resources: *The Delphi Method: Techniques and Applications* (Linstone and Turoff 1975; http://www.is.njit.edu/pubs/delphibook/). This is a free, downloadable book of readings about Delphi and its various applications written by recognized authorities on the use of the technique. Free software to support a Delphi Process is available at http://armstrong.wharton.upenn.edu/delphi2/. It provides a software platform for conducting a Delphi, including all needed forms.

A3 Focus Groups

In focus groups a group of persons selected to represent particular viewpoints or stakeholder groups is invited to participate in a controlled discussion. For example, a focus group of elderly residents of a study area could be assembled to discuss the feasibility and applicability of potential FRM measures. While somewhat similar to workshops, focus groups differ in that specific individuals or groups are selected to participate and specific questions are discussed, usually in a controlled order. Focus groups are identified in OMB Paperwork Reduction Act guidance restricting the use of questionnaires and surveys to more than 10 persons without OMB approval, so in practice focus groups should be limited to no more than nine persons without OMB clearance. The primary benefit of focus groups over questionnaires completed privately is thought to be that groups can discuss questions and reach conclusions that may be different from what would be obtained without the benefit of group discussion. For more information on focus groups, see Marshall and Rossman (1999).

A4 Historical Analysis

A good preliminary step to build greater understanding of a study area or water resources issues is to consult histories that have focused on these topics. Historical treatments of an area's development can often be found in comprehensive plans for the area or in histories prepared by local historical societies.

A5 Independent Studies and Projections

While it is possible for the analyst to develop projections of demographic variables such as population, income, and employment, it is much more advisable to use projections prepared by official government sources. In some cases there may be several projections from official sources, and they may not agree. The analyst should array such projections, discuss their methods and purposes, and then specify the reasons for the choice of projection used. Similarly, it is possible that there may be an official projection for a larger area encompassing the study area. In such cases it is advisable for the analyst to begin with this projection and then carefully lay out a rationale for arriving at the smaller area projection. The shift-share methodology can be especially useful for deriving smaller area projections from projections of larger areas (Knudsen 2000).

A6 Interviews

Interviews are a guided conversation for the purpose of collecting information. The interviewer generally asks one or two relatively unstructured questions to begin the conversation with the interviewee and then lets the process take over. Such guided conversations are likely to be useful in providing the analyst with a better understanding of stakeholder issues and concerns that can help in developing planning objectives and measures[1]. Additionally, the interview process can often develop and strengthen relationships that can have relevance in the planning process. Interviews can be conducted face-to-face or by telephone. Generally, it is preferable to conduct an interview in person so that the interviewer can make use of nonverbal cues to help guide the interview.

A7 Secondary Data Collection and Analysis

Secondary data, which are data that have been collected by someone else for another purpose (Cnossen 1997), can be an economical and efficient source of information (Babbie 1979). As research questions are formulated, the analyst should try to identify other potential sources of information and studies that have been conducted that address the questions. For example, a university or emergency management agency may have conducted a survey of residents after a flood. Such surveys can provide important information and might substitute for the expense and administrative burden of conducting your own survey. Likely sources of secondary information include universities (including master's theses), local government reports and planning documents, trade journal articles, and technical reports and studies. The best way of finding such information is to consult experts in the topic areas.

Since secondary data have been collected by someone else for another purpose, care should be exercised in evaluating the quality of the data. Attention should be paid to who has collected the data and for what purpose. For example, data presented by an organization with a particular point of view to promote are likely to be more suspect than survey data presented in a peer-reviewed scholarly journal. Similarly, finding broad

[1] The author once conducted interviews with residents from all households on an island in the Mississippi River that had suffered a devastating flood and forced the complete evacuation of residents from the island. The in-depth understanding gained from the interviews about residents' experiences, losses, and efforts to recover proved invaluable in helping to formulate plans that addressed resident concerns.

patterns of agreement among data from several sources is likely to create greater confidence in secondary data.

A8 Stakeholder Identification Methods

Stakeholders are those individuals and groups that have a stake in the outcome of a planning process. Stakeholders can be identified on the basis of interests in water resources issues that they might have (Creighton 2005). Three interrelated methods can be used to identify stakeholders. The first approach identifies those stakeholders who obviously should be included based on their correspondence to the interest factor, e.g., a local planning association or the local Realtors Association. The second method uses already identified stakeholders as a source to identify additional stakeholders. Once an initial list of stakeholders has been identified, personal interviews can be conducted with representatives of the stakeholder groups to talk about perceptions of the current situation and future challenges and opportunities. During interviews it is desirable to add to the stakeholder list by asking stakeholders who else would have an interest in the water resources issue. The third approach uses analysis to identify stakeholders. It might also be useful to review past decisions that relate to the water resources issue, letters to the editor in local papers, and news articles about water-resources-related issues to identify groups and individuals that have been active. The process of stakeholder identification is constant, not just something that is done at the beginning of the planning process. A stakeholder database organized by categories (e.g., elected officials, agencies, community groups, and media) should be developed and kept up to date.

A9 Surveys

Surveys are standardized sets of questions posed to others to answer. Surveys might be administered to flood victims about effects experienced and actions being taken to recover after a flood event. Similarly, surveys of at-risk, socially vulnerable populations could be conducted to identify their special needs. Survey questions are sometimes asked in face-to-face situations or via telephone. In these circumstances the researcher completes the survey form as the respondent answers the questions posed by the researcher. In other cases a questionnaire is provided to respondents with written instructions for the respondent to follow. Upon completion the respondent returns the form to the researcher. Standardized surveys are widely used to elicit information from

stakeholders. They provide a way of obtaining a snapshot of views, attitudes, priorities, evaluations, etc., at one moment in time.

Because of their apparent ability to provide information about a wide range of pubic governance issues, they can be overused and become a burden on the public. The Office of Management and Budget (OMB), following the wishes of Congress, has issued stringent rules restricting the ability of government agencies to use standardized surveys. However, the Corps of Engineers has obtained a clearance from OMB to employ questionnaires for collecting planning data. The rules governing the use of OMB-approved questions are contained in ER 1165-2-503 (31 Oct 07). There are numerous surveys covering many topics (e.g., customer satisfaction, environment, flood damage reduction, navigation, operations, public participation, recreation management and planning). The surveys and instructions for their use are located at the following website: http://www.iwr.usace.army.mil/index.php?option=com_content&view=article&catid=39%3Apub-stories&id=84%3Aomb-approved-surveys&Itemid=3. The analyst may want to consider using some of the approved questions to survey stakeholders, weighing the time required for Corps approval, the technical difficulties of drawing a valid sample, and the value of the information obtained against the time and effort needed to obtain it versus other, less cumbersome means that might be available. Should the analyst conclude that a survey is the best approach for gathering needed data, careful thought should be given to obtaining the assistance of a qualified survey research expert.

It is also advisable to do a thorough literature review and web search to find out if surveys have already been done by other government agencies or by university survey research organizations that touch on the topic of interest. While such surveys may not be exactly applicable, they may yield sufficient information to eliminate the need to go through the time, expense, and aggravation of an in-house survey.

A10 Workshops

The term “workshop” refers to a small group meeting, convened to achieve a specific purpose and led by a facilitator. The facilitator attends to the process of the meeting, helping participants stay focused on the meeting objective, and employs structured problem solving processes to help participants work through their issues of concern. Workshops are often used in planning to bring stakeholders together to identify issues of

concern, to identify possible ways that a water resources problem could be addressed, and to evaluate alternatives. Workshops function best when they have 8 to 15 participants. Larger groups can be broken down into workgroups that can perform tasks in the small group workshop environment and then reconvene into the larger group to report and discuss their activities. This large group—small group—large group format is only one of many variations for workshops. Designing and conducting workshops is a skill that requires knowledge of group dynamics, structured problem solving techniques, and experience gained from actual practice.

A visioning workshop focuses on developing preferred visions of the future. Participants would likely be invited to participate based on particular interests or points of view they represent. Facilitators would likely lead the group in exercises to describe what the future should look like and then focus more explicitly on key themes that are present in visions. Work would then generally be devoted to comparing, contrasting, and integrating visions; applying the vision to particular issue areas; and identifying action steps needed to make the preferred vision a reality.

Appendix B: SoVI Computation

Steps in creating a SoVI analysis are shown below. [1] Comments and observations about performing a step are shown in italics.

1. Obtain and create SoVI variables. Download the requisite variables from the U.S. Census Data Engine and create SoVI variables. *The Census American Fact Finder on-line interface (Figure B1) provides a simple way to find and download census data at all levels of geography. Commercial products are also available that provide easier access to census data but that generally require paying a fee for access.*

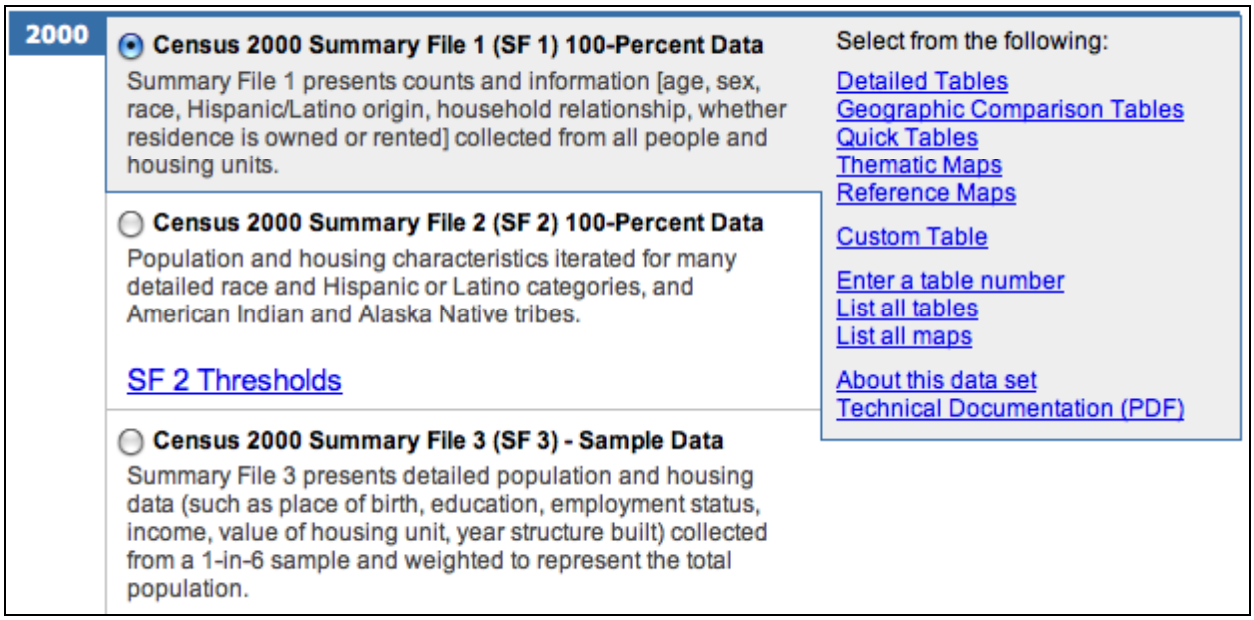

Figure B1. Census Bureau web page showing data groupings.

The Census Bureau assigns a code to a data field such that the first letter together with the three numerals indicate a table, while the next three numerals indicate a column in that table. The code P012025, for example, means that the data will be found in Table P12, data column 25. When searching for tables by table number at the web site, the researcher should omit leading zeroes. Enter "P12" to find the table that contains variable P012025. Table B1 shows the SoVI variables and their location in U.S. Census data tables and the formulas to

[1] Information presented in this Appendix extracted from Koch (2009) and Cutter et al. (2009).

create them. For example, creating the variable QPOP65O "Percent of population 65 or older" requires the computation and summing of a number of sub-variables: males 65 and 66, 67 to 69, 70 to 74, 75 to 79, 80 to 84, and 85 and over, as well as the same sub-variables for females, divided by the total population and multiplied by 100.

Table B1. Variables used in SoVI showing location in census tables and computation procedures.

Name	Variable	Source	Equation (using census variables)
MEDAGE00	Median Age 2000	Census Data Engine SF1	[P013001]
QBLACK00	Percent African American 2000	Census Data Engine SF1	((Total African Americans [P003004]) / (Total Population [P001001])) * 100
QINDIAN00	Percent Native American 2000	Census Data Engine SF1	((Total American Indian or Alaska Natives [P003005]) / (Total Population [P001001])) * 100
QASIAN00	Percent Asian and Hawaiian Islanders 2000	Census Data Engine SF1	((Asian [P003006] + Native Hawaiian [P003007]) / (Total Population [P001001])) * 100
QSPANISH00	Percent Hispanic 2000	Census Data Engine SF1	((Total Hispanic [P004002]) / (Total Population [P001001])) * 100
QKIDS00	Percent of population under 5 yrs of age 2000	Census Data Engine SF1	((Total Population Under Age 5 [P012003] + [P012027]) / (Total Population [P001001]) * 100
QPOP65O00	Percent of population 65 and over 2000	Census Data Engine SF1	((Total population over age 65 [P012020] + [P012021] + [P012022] + [P012023] + [P012024] + [P012025] + [P012044] + [P012045] + [P012046] + [P012047] + [P012048] + [P012049]) / (Total population [P001001])) * 100
PPUNIT00	Average number of people per household 2000	Census Data Engine SF1	(Total number of people in occupied housing units H010001) / (Total Housing Units H001001)
QRENTER00	Percent renter-occupied housing units 2000	Census Data Engine SF1	((Total Renter-Occupied Housing Units [H004003]) / (Total Occupied Housing Units [H010001])) *100
NRRESPC00	Per capita residents in nursing homes 1991	Census Data Engine SF1	((Total number of residents in nursing homes [P038006] +[P038015] +[P038024] +[P038034] +[P038043] +[P038052]) / (Total Population [P001001]))
QFEMALE00	Percent female population 2000	Census Data Engine SF1	((Total number of females [P012026]) / (Total Population [P001001])) * 100
QFHH00	Percent female-headed households, no spouse present 2000	Census Data Engine SF1	((Total number of female headed households [H017047] + [H017013]) / Total Households [H017001])) * 100
HOSPTPC00	Per capita number of community hospitals 1997	Census Data Engine SF1/ GNIS US Hospitals	(Total number of hospitals (GNIS US Hospitals - Converted X, Y data to point files in GIS. Automatically counted points per census tract) / (Total Population [P001001]) (Citation)

HODENT00	Number of housing units per square mile 2000	Census Data Engine SF1/ ArcMAP 9.3	(Total number of housing units[H001001] / Land Area in Square Miles ('Calculate Geometry' Function in ArcMAP 9.3)
PERCAP00	Per Capita Income (in dollars) 2000	Census Data Engine SF3	[P082001]
MHSEVAL00	Mean Value of Owner-Occupied Housing Units 2000	Census Data Engine SF3	(Aggregate House Value [H086001]) / (Owner Occupied Housing Units [H007002])
M_C_RENT00	Mean Contract Rent 2000	Census Data Engine SF3	(Aggregate Contract Rent [H058001]) / (Renter-Occupied Housing Units ([H007003])
PHYSICN00	Number persons per 100,000 population employed as healthcare practitioners and technical occupations 2000	Census Data Engine SF3	(Total number of persons employed as healthcare practitioners and technical healthcare occupations [P050020] + [P050067]) / (Total Population [P001001]) / 100000)
MIGRA00	Foreign Born (born 1990- March 2000)	Census Data Engine SF3	((Total number of persons immigrating from 1990-2000 ([P022002] + [P022003]) / Total number of foreign born persons ([P021013])) * 100
QCVLUN00	Percent civilian unemployment 2000	Census Data Engine SF3	((Total number of people in the civilian labor force unemployed [P0043007] + [P0043014]) / (Total number of people in the civilian labor force [P0043005] + [P0043012])) * 100
QRICH00	Percent of households earning $100,000 or more 2000	Census Data Engine SF3	((Total number of households with income over 100,000 [P052014]+ [P052015] + [P052016] + [P052017]) / (Total number of households with income P052001)) * 100
QPOVTY00	Percent living below poverty level 2000	Census Data Engine SF3	(Total number of people with income below poverty level [P087002]) / Total Population [P001001])) * 100
QRFRM00	Percent rural farm population 2000	Census Data Engine SF3	((Total Farm Population [P005006]) / (Total Population [P001001])) * 100
QMOHO00	Percent of housing units that are mobile homes 2000	Census Data Engine SF3	((Total number of mobile homes [H030010]) / Total Housing Units [H001001])) * 100
QED12LES00	Percent of population 25 years or older with no high school diploma 2000	Census Data Engine SF3	((Total number of people over 25 with less than a high school diploma [P037003]+[P037004]+[P037005]+[P037006]+[P037007]+[P037008]+[P037009]+[P037010]+[P037020]+[P037021]+[P037022]+[P037023]+[P037024]+[P037025]+[P037026]+[P037027]) / (Total population over age 25([P008026]+[P008027]+[P008028]+[P008029]+[P008030]+[P008031]+[P008032]+[P008033]+[P008034]+[P008035]+[P008036]+[P008037]+[P008038]+[P008039]+[P008040]+[P008065]+[P008066]+[P008067]+[P008068]+[P008069]+[P008070]+[P008071]+[P008072]+[P008073]+[P008074]+[P008075]+[P008076]+[P008077]+[P008078]+[P008079])) * 100

QCVLBR00	Percent of population participating in the labor force 2000	Census Data Engine SF3	((Total number of people in civilian labor force [P043005] + [P043012]) / (Total Population [P001001])) * 100
QFEMLBR00	Percent females participating in the labor force 2000	Census Data Engine SF3	((Total number of females in civilian labor force [P043012]) / (Total number of people in the Civilian Labor Force [P043005] + [P043012])) * 100
QAGRI00	Percent employment in farming, fishing, and forestry occupations 2000	Census Data Engine SF3	((Total number of persons employed in Agriculture, Forestry, Hunting, Fishing and Mining Industries [P049003] + [P049030]) / (Total number of people in the Civilian Labor Force [P043005] + [P043012])) * 100
QTRAN00	Percent employed in transportation, communications, and other public utilities 2000	Census Data Engine SF3	((Total number of persons employed in transportation, warehousing and utilities industry [P049010] + [P049037]) / (Total number of people in the Civilian Labor Force [P043005] + [P043012])) * 100
QSERV00	Percent Employed in service industry 2000	Census Data Engine SF3	(Total number of persons employed in the service industry ([P050023] + [P050070]) / Total number of people in the Civilian Labor Force ([P043005] + [P043012])) * 100
QURBAN00	Percent urban population 2000	Census Data Engine SF3	((Total number of persons living in urban areas [P005002]) / (Total Population [P001001])) * 100
QSSBEN00	Percent of population collecting social security benefits 2000	Census Data Engine SF3	((Total number of social security recipients [P062002]) / (Total population [P001001])) * 100

2. Verify the accuracy of data obtained by using descriptive statistics such as the minimum and maximum values. Check for missing values for the unit of analysis. If some cells have a missing value, substitute the mean value for the variable in its place. The statistical procedure will not run properly with missing values. The computation of a large number of variables is time consuming and tedious work that can result in errors. Patience and checking work are necessary.
3. Normalize the input variables through the creation of z-scores with a mean of 0 and a standard deviation of 1. Use the Standardize function in Excel to generate the normalized distribution of scores for each variable. Excel functions used in creating the SoVI data file are shown in Table B2.

Table B2. Excel functions used in SoVI analysis.

Excel function	Application in SoVI analysis
ABS	Absolute value
AVERAGE	Mean, used in calculating Z values
STDEV	Standard deviation, used in calculating Z values
STANDARDIZE	Calculate Z values
FREQUENCY	Identify census tracts within each of five ranges of Z values to plot histogram
COUNTIF	Count total number of census tracts for each range of Z values
Conditional formatting (optional)	Shade spreadsheet cells according to Z value within each cell
File > Save As > CSV (comma delimited)	Export Z values and SoVI values to be mapped

4. Perform the principal components analysis (PCA) using a varimax rotation and Kaiser criterion for component selection (e.g. eigenvalues greater than 1.0). Table B3 shows output from the PCA procedure. The varimax rotation tends to load each variable highly on only one component (Table B4). *PCA is available in large statistical software packages like SPSS and SAS.*

Table B3. Percent variance explained (SPSS).

	Initial Eigenvalues			Rotation sums of squared loadings		
Component	Eigenvalue	% of Variance	Cumulative %	Eigenvalue	% of Variance	Cumulative %
1	6.981	21.815	21.815	4.652	14.538	14.538
2	4.282	13.382	35.197	4.313	13.477	28.014
3	3.982	12.444	47.64	3.8	11.875	39.89
4	1.961	6.129	53.77	3.198	9.993	49.882
5	1.628	5.088	58.858	1.776	5.551	55.433
6	1.32	4.125	62.982	1.776	5.549	60.983
7	1.191	3.723	66.705	1.561	4.879	65.862
8	1.076	3.362	70.067	1.32	4.126	69.988
9	1.001	3.129	73.196	1.027	3.209	73.196

Table B4. Rotated component matrix showing highest correlated variables with PCA components.

Component:	1	2	3	4	5	6	7	8	9
Zscore(qblack)	0.800	-0.224	0.057	-0.134	-0.005	0.221	-0.192	0.018	-0.075
Zscore(qindian)	0.003	-0.044	-0.053	-0.043	0.067	-0.022	-0.015	-0.026	0.945
Zscore(qasian)	-0.291	-0.275	0.442	0.048	0.253	-0.127	0.084	0.017	0.007
Zscore(qspanish)	0.023	-0.121	0.146	-0.030	-0.053	-0.141	0.871	-0.005	0.011
Zscore(qkids)	0.285	-0.693	-0.082	-0.072	-0.135	0.262	0.063	-0.056	0.109
Zscore(qpop65o)	-0.042	0.943	0.020	0.038	-0.083	0.160	0.082	0.136	0.037
Zscore(medage)	-0.257	0.882	-0.026	0.181	-0.201	0.059	0.026	0.063	0.005
Zscore(qfemale)	0.071	0.183	0.063	0.050	0.009	0.892	0.018	0.039	-0.020
Zscore(ppunit)	-0.004	-0.726	-0.017	-0.002	-0.471	0.099	0.224	-0.007	0.089
Zscore(qrenter)	0.372	0.005	0.393	-0.139	0.672	-0.110	0.055	0.153	-0.095
Zscore(qfhh)	0.799	-0.294	0.078	-0.216	-0.064	0.341	0.006	-0.002	0.016
Zscore(nrrespc)	-0.029	0.127	0.044	-0.073	0.008	0.142	0.061	0.815	0.050
Zscore(qcvlun)	0.658	-0.089	0.057	-0.119	0.209	0.032	0.000	0.081	-0.003
Zscore(percap)	-0.316	0.247	0.147	0.801	0.009	-0.041	-0.028	-0.056	0.005
Zscore(qpovty)	0.837	-0.079	-0.119	-0.201	0.234	0.100	0.077	0.029	0.005
Zscore(physicn)	-0.509	-0.044	0.185	0.402	0.090	0.199	-0.212	0.011	-0.041
Zscore(qrfrm)	-0.028	-0.043	-0.809	-0.027	0.033	0.008	-0.047	-0.042	-0.061
Zscore(qmoho)	-0.084	0.084	-0.721	-0.300	-0.121	-0.117	-0.113	-0.096	0.084
Zscore(qcvlbr)	-0.568	-0.429	0.153	0.097	0.369	0.097	-0.017	-0.147	-0.136
Zscore(qfemlbr)	0.259	-0.079	0.254	-0.218	-0.018	0.669	-0.221	-0.078	-0.016
Zscore(qagri)	0.115	0.001	-0.729	-0.017	0.061	-0.119	0.141	0.004	0.064
Zscore(qtran)	-0.120	-0.183	-0.058	-0.185	-0.516	0.062	0.189	-0.061	-0.196
Zscore(qssben)	0.043	0.939	-0.056	0.005	-0.058	0.156	0.013	-0.011	0.029
Zscore(migra)	-0.025	-0.280	-0.117	-0.104	0.564	0.131	0.224	0.058	0.026
Zscore(qurban)	0.104	0.042	0.854	0.115	0.086	0.094	0.181	0.054	0.001
Zscore(hodent)	0.138	0.248	0.424	0.036	0.261	0.075	0.538	-0.131	-0.096
Zscore(hosptpc)	0.136	0.042	0.075	0.004	0.124	-0.157	-0.110	0.708	-0.077
Zscore(m_c_rent)	-0.368	0.044	0.584	0.447	-0.011	-0.006	0.256	-0.040	-0.021
Zscore(mhseval)	-0.226	0.076	0.150	0.853	0.069	-0.105	0.027	-0.038	-0.043
Zscore(qserv)	0.563	0.118	0.227	-0.396	0.053	-0.072	0.037	-0.105	0.015
Zscore(qrich)	-0.321	-0.018	0.169	0.867	-0.114	-0.032	-0.012	-0.026	0.002
Zscore(qed12les)	0.647	-0.055	-0.398	-0.398	-0.027	-0.033	0.257	0.109	0.025

5. Interpret and name the resulting components. This is done by examining the correlations between the variables and the components given in the loadings matrix output of the PCA to determine what characteristics are

being represented and if they have a tendency to increase or decrease social vulnerability. For example, in the SAD SoVI, the variables QPOVTY, QBLACK, and QFFHH were most closely associated with component 1, which indicated that this component was tapping into a poverty and race theme or dimension (Table B5).

It is sometimes found that the variables associated with a factor indicate lower social vulnerability. For example, in the SAD SoVI, several variables indicating wealth were strongly associated with a factor. Since a positive value on this factor would tend to decrease social vulnerability, the inverse of the corresponding factor score is used (in other words, the factor score is multiplied by –1). Table B5 shows where such an operation is needed by the "Cardinality" column.

Table B5. Social vulnerability analysis output for SoVI.*

Component	Cardinality	Name	% Variance Explained	Most Influential Variables
1	+	Poverty and race	14.5	Qpovty 0.837 QBlack 0.800 Qfhh 0.799
2	II	Age	13.5	Qpop65 0 .943 Qssben 0.939 Medage 0.882
3	II	Urban/Rural	11.9	Qurban 0.854 Qrfrm –0.809 Qagr –0.729 Qmoho –0.721
4	–	Wealth	10.0	Qrich 0.867 Mhseval 0.853 Percap 0.801
5	+	Migrants and renters	5.6	Qrenter 0.672 Qmigra 0.56
6	+	Gender	5.5	Qfemale 0.892 Qfemlbr 0.669
7	+	Ethnicity-Hispanic	4.9	Qspanish 0.871
8	+	Special needs	4.1	Nrrespc 0.871 Hosptpc 0.708
9	+	Race and ethnicity	3.2	Qindian 0.945
Total Explained Variance			73.2	

*SoVI Score = (Principal component 1) + abs(Principal component 2) + abs(Principal component 3) – (Principal component 4) + (Principal component 5) + (Principal component 6) + (Principal component 7) + (Principal component 8) + (Principal component 9)

6. Place all the components with their adjustments into an additive model and sum to generate the overall SoVI score for the place.

   So, for example, in the Table B6, the SoVI score for Tract 1 is computed as:

   Factor 1 (0.26698) + Factor 2 (–2.31238) + Factor 3 (0.15594) + Factor 4 (0.42792) + Factor 5 (0.59988) + Factor 7 (–0.92015) + Factor 8 (3.76249) = 5.65

Table B6. Factor scores for Chatham SoVI aggregated as SoVI score.

Tract	Factor 1 (+)	Factor 2 (+)	Factor 3 (II)	Factor 4 (+)	Factor 5 (II)	Factor 6 (+)	Factor 7 (–)	Factor 8 (+)	SoVI Score
	Race and Class	Elderly	Housing Tenure	Gender	Urban/ Rural	Unemployed Female Headed Household	Hospitals	Extractive Industry	
Tract 1	0.26698	–2.31238	0.15594	0.42792	0.59988	3.67319	–0.92015	3.76249	**5.65**
Tract 3	–0.50987	–1.34869	2.72797	–1.40467	0.31661	–0.8703	0.86532	–0.5172	**–0.74**
Tract 6.01	1.41266	0.93249	0.16825	0.36282	0.63225	–0.50052	0.08178	2.44455	**5.53**
Tract 8	–1.43861	–1.23538	3.06355	0.09382	0.42289	–0.21004	0.82402	–0.33424	**1.19**
Tract 9	–1.38135	2.10678	3.24515	–0.03863	0.00268	0.59333	0.90737	–0.05972	**5.38**
Tract 11	0.98946	–0.67101	0.54855	0.28349	0.37732	–0.01946	0.21027	0.55252	**2.27**
Tract 12	1.22937	–0.26878	0.28505	0.5232	0.21674	2.1867	–0.31816	–0.4826	**3.37**
Tract 13	–0.02709	–1.64889	1.90275	–0.01015	0.02348	–0.90794	0.11555	–0.14301	**–0.70**
Tract 15	0.47815	–0.61696	2.91979	–0.19623	0.02518	–0.9775	0.74153	–0.99502	**1.38**
Tract 18	1.30362	0.00486	1.52961	0.49067	0.0781	1.2142	0.4256	–0.60398	**4.44**
Tract 19	1.42018	–0.61595	1.42643	0.35797	0.09819	–1.341	0.41044	–0.28028	**1.48**
Tract 20	1.3731	0.20636	0.52177	0.4061	0.03916	–0.06194	0.60721	–0.7437	**2.35**
Tract 21	1.19326	0.23902	0.19916	0.80317	0.71268	–0.51905	0.66834	–0.37403	**2.92**
Tract 22	0.64603	–0.13455	0.01756	0.40252	0.14387	0.53024	0.16807	–0.60112	**1.17**
Tract 23	1.36401	1.49257	0.30298	0.04063	0.47877	0.09043	0.98889	4.4513	**9.21**
Tract 24	0.9466	0.3003	0.00997	0.42879	0.23647	0.51527	0.45773	–1.11572	**1.78**
Tract 25	0.89474	1.94398	1.75953	–0.01199	0.28498	–0.39351	–4.1865	–0.41273	**–0.12**
Tract 26	1.03498	0.21997	0.21951	0.32723	0.46688	–0.55085	0.82032	–0.37144	**2.17**
Tract 27	1.33218	0.43583	0.50252	0.60249	0.51391	–1.02814	1.03018	–0.79643	**2.59**
Tract 28	1.15117	0.61495	0.0363	0.4653	0.28317	–0.18836	–0.88608	–0.46259	**1.01**

7. SoVI scores are then mapped using a classification (e.g. quintile) based on standard deviations from the mean (e.g. with scores ≥ 0.5 standard deviation indicating higher levels of social vulnerability).

Appendix C: Social Vulnerability and Place Vulnerability Analysis Methods and Application for Corps Planning: Technical Analyses

Social Vulnerability and Place Vulnerability Analysis Methods and Application for Corps Planning: Technical Analyses

By

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Introduction

This project provides an assessment of quantitative procedures for social vulnerability and place vulnerability analyses for US Army Corps Civilian Works plan formulation/evaluation and Emergency Management planning. The scope of work included a short Literature review on the Social Vulnerability Index (SoVI), development of a simplified SoVI (termed SoVI-Lite) for use in Corps planning, and a technical appendix documenting the procedures for constructing the metric and the sensitivity analyses used to compare it to the original.

Background on the Social Vulnerability Index (SoVI)

This section reviews the original development of the Social Vulnerability Index (SoVI), applications of SoVI in research and practice, and available critiques and limitations of the metric. Social vulnerability describes those characteristics of the population that intervene between natural processes and the built environment to redistribute the risks and impacts of natural hazards, thus creating differential social burdens of hazards (Cutter et al. 2003). This helps to explain why some communities experience the hazard differently, even though they have the same level of flooding or storm surge inundation. Understanding the differential impacts of hazards (as a product of the social vulnerability, not differences in exposure or risk), is a critical element in formulating comprehensive flood risk management programs at the landscape or watershed scale. Yet, few if any programs routinely incorporate social vulnerability into such efforts, preferring instead to focus exclusively on cost-benefit analyses, and not the differential spatial impact of such analyses on communities.

Within the social science and disasters literature, there is a rich tradition of research focused on those social factors that increase or decrease the impact of specific natural hazard events on the local population. Summaries of such work are readily available(Heinz Center, 2002; Mileti, 1999; National Research Council, 2006; Tierney, Lindell, & Perry, 2001). Key social indicators that consistently appear in the literature as influencing pre-impact preparedness and post-event response and recovery include attributes such as socioeconomic status (wealth, education, occupation), age (elderly populations and young children are more vulnerable); gender; race and ethnicity; employment and employment sector; and special needs populations. However, it is not just the proportion of residents in these broad categories that is important, but instead how race, socioeconomic status, and gender interact to produce socially vulnerable populations. Selecting one variable (race, gender, socioeconomic status) does not adequately capture communities described as African American female-headed households below the poverty level, because not all African Americans are in poverty; not all female-headed households are African American; and not all people in poverty are females or female-headed households.

The Social Vulnerability Index, originally formulated by Cutter et al. (2003), is a multi-dimensional scale dependent, spatially reliant algorithm for capturing a snapshot of the socio-economic and demographic character of a place as a means of understanding the propensity of a place to either resist or be particularly influenced by any disaster event. The original social vulnerability index was calculated by analyzing data at a county level for the United States (Cutter et al. 2003). Since then additional applications have downscaled the index to finer geographic units (cities, census tracts, census block groups) to insure the same capacity for explanation and spatial pattern recognition found in the

county level assessment (Cutter et al. 2006; Burton and Cutter, 2008; Wood et al. 2009). The temporal consistency of the index has been established using decadal census data from 1960-2000 (Cutter and Finch, 2008). Lastly, there is significant sensitivity testing on the algorithm to confirm the robustness of the downscaling (Schmidtlein et al. 2008).

SoVI synthesizes 42 socioeconomic and built environmental variables derived primarily from the U.S. Census through a statistical procedure called principal components analysis. The input variables were based on the extensive social science research literature on those factors that influence a community (and thus its residents) to prepare for, respond to, and recover from hazards and disasters. The variables were first standardized then input into the principal components analysis to reduce the number of variables into a smaller set of multi-dimensional factors. For each factor, the directionality was determined by expert judgment so that positive loadings were associated with increasing vulnerability, and negative loadings with decreasing vulnerability. Once the directionality of the factors was established, they were summed to produce the numerical SoVI score for each spatial unit (county, census tract). The scores represent a relative measure of social vulnerability (place A is more vulnerable than place B), not an absolute measure (place A is 10 times more vulnerable than place B). To graphically represent the relative nature of the metric, the SoVI scores are mapped using standard deviations or some other classification scheme (e.g. quantiles).

Downscaling Social Vulnerability

Because SoVI is rooted in the fact that different people behave, respond to, and react to disasters in diverse ways, the main concept of the index revolved around identifying characteristics of the population and how they differ across space (and through time). It is important to note that SoVI was originally calculated at the County level for the entire United States, while this project is being undertaken at the US Census Tract level. We have identified some insidious issues and possible sources for computation errors related to the choice of enumeration unit, when downscaling.

1. There are a number of census tracts (~133) with no population. These tracts were excluded from our analysis because the SoVI is intrinsically related to human occupancy of the enumeration unit.

2. The calculation of median house value (used in previous versions of SOVI) could not be used at the US Census Tract level because there are tracts in which the median value is greater than $1,000,001 (the maximum that the US Census displays). To circumvent this issue we calculated this value using aggregate house value (not limited by US Census) divided by the number of housing units. This discovery and change in calculation proved fruitful by increasing the mean house value by ~$200,000. This issue was not present at the county level because of the number of cases involved in the calculation.

3. The calculation of median rent value (used in previous versions of SOVI) could not be used at the US Census Tract level because there are tracts in which the median value is greater than $1,001 (the maximum that the US Census displays). This value is now calculated using aggregate contract rent divided by the number of renter occupied units. This solution also proved to be adequate as the aggregate contract rent (in some tracts) was higher than the original median rent. This was not an issue at the county level as median rents were much lower than the cap.

4. Previous calculations of percent female-headed households only included those single female heads of households in owner occupied housing. For this calculation, we included female heads of households in renter occupied housing as well. This corrects a mistake in previous SoVI versions.

5. Some tracts had a zero value for people per unit and housing density yet had a significant population. This is explained by the presence of a prison or other state of federal institution with a significant resident population, yet no housing units. This results in a people per housing unit value of zero and accounts for zero values in mean house value and mean contract rent in these census tracts as well.

Not all of the original variables used to compute SoVI are available at the tract level (birth rate, voting, debt/revenue ratio, land in farms, population change). Further, we eliminated those variables that were more indicative of built environment exposure (density of manufacturing or commercial establishments) rather than social indicators. This resulted in 32 variables used to construct SoVI, however, based on the sensitivity tests (Schmidtlein et al. 2008), the metric remains robust with fewer variables in the downscaling process.

SoVI for the USACE South Atlantic Civilian Division

The first step was to construct SoVI at the census tract level for the study area, the Corps' South Atlantic Civilian Division (SACD). We used the standard SoVI recipe with the 32 input variables to create the SoVI at the tract level for the South Atlantic Division ($SoVI_{TR}$-SACD) (http://webra.cas.sc.edu/hvri/docs/SoVIRecipe.pdf). This became the baseline for comparison as we evaluated the various permutations on computing SoVI-Lite.

Nine components were generated in the $SoVI_{TR}$-SACD, which explain 73% of variation in the data. These remain consistent with other versions of SoVI in both the average number of factors generated and in the percentage of explained variance (Table 1).

In addition to computation of $SoVI_{TR}$ for the South Atlantic Civilian Division, it was necessary to map the scores to ascertain the spatial distribution. Figure 1 shows the geographic variability in social vulnerability within the SACD, mapped using the standard deviation classification methods. Tracts in red have the highest levels of social vulnerability; those in dark blue have the lowest.

The importance of the mapping is twofold. First, even if the statistical correlation between $SoVI_{TR}$ and a SoVI-Lite permutation is high; we wanted to insure that the spatial pattern was preserved and replicated. Second, because the SoVI is place-based, we wanted to insure that the change in categories (e.g. moving from high to medium, or medium to low) had little impact on the overall comparisons.

Table 1 Social Vulnerability Analysis Output for $SoVI_{TR}$-SACD*

Component	Cardinality	Name	% Variance Explained	Most Influential Variables	
1	+	Poverty and race	14.5	Qpovty QBlack Qfhh	0.837 0.800 0.799
2	||	Age	13.5	Qpop65 Qssben Medage	0 .943 0.939 0.882
3	||	Urban/Rural	11.9	Qurban Qrfrm Qagr Qmoho	0.854 -0.809 -0.729 -0.721
4	-	Wealth	10.0	Qrich Mhseval Percap	0.867 0.853 0.801
5	+	Migrants & renters	5.6	Qrenter Qmigra	0.672 0.56
6	+	Gender	5.5	Qfemale Qfemlbr	0.892 0.669
7	+	Ethnicity-Hispanic	4.9	Qspanish	0.871
8	+	Special needs	4.1	Nrrespc Hosptpc	0.871 0.708
9	+	Race & ethnicity	3.2	Qindian	0.945
Total Explained Variance			73.2		

*$SoVI_{TR}$-SACD Score = (Principal component 1) + abs(Principal component 2) + abs(Principal component 3) – (Principal component 4) + (Principal component 5) +(Principal component 6) + (Principal component 7) + (Principal component 8) + (Principal component 9)

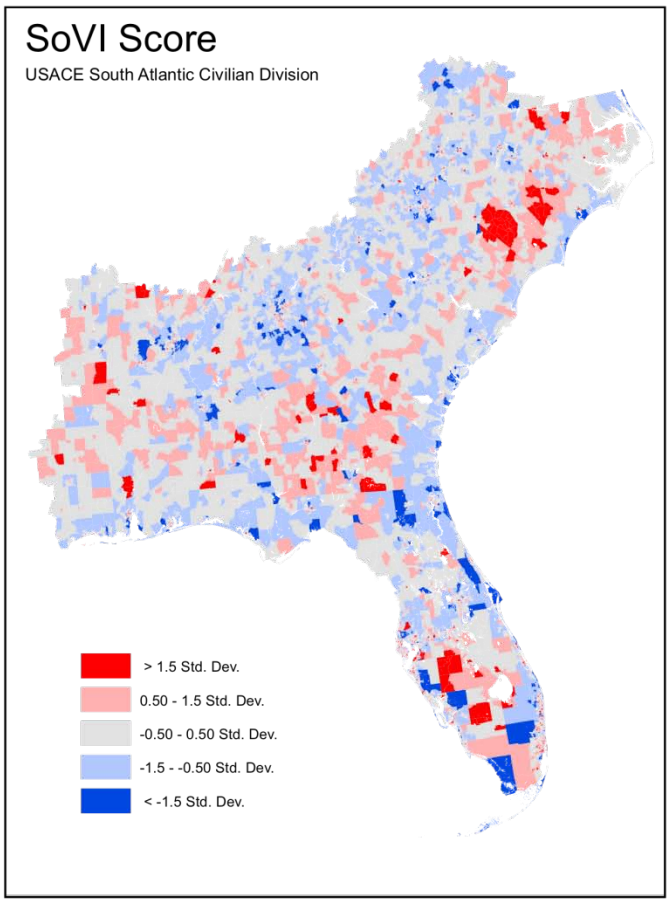

Figure 1 USACE South Atlantic Division $SoVI_{TR}$ score

Calculating SoVI Lite

Eight distinct metrics were used to create different statistical approaches to constructing simplified versions of the Social Vulnerability Index and assessing their robustness in simplifying SoVI. For each test, we briefly describe the equation used followed by an analysis of the metric's strengths and weaknesses in matching the original $SoVI_{TR}$-SACD. Specific details on the procedures and outcomes are in the technical appendix (Technical Appendix). First, each variant was statistically correlated with the original $SoVI_{TR}$-SACD using a bivariate Pearson's R correlation. Second, each configuration was mapped to ascertain spatial similarities to the $SoVI_{TR}$-SACD.

6

SoVI Lite 1: Highest Variable Correlation with Component

The first simplifying test took the variable with the highest loading on each factor and constructed the SoVI score from that; in other words, reducing the variables from 32 to nine, while maintaining the representation of each component of social vulnerability. The variable with the highest correlation coefficient on each component became the sole (or proxy) indicator of that component. For example, for the poverty and race component, poverty had the highest correlation (R=.837), therefore it was selected to represent Component 1. The z-scored value for each of the nine variables (representing each of the components) is summed using the cardinality [positive (+), negative (-), or absolute (ABS)] associated with each variable's correlation coefficient in the initial creation of $SoVI_{TR}$-SACD.

The SoVI Lite 1 equation is:

SoVI_Lite 1= (Zqpovty) + ABS(Zqpop65o) + ABS(Zqurban) – (Zqrich) + (Zqrenter) + (Zqfemale) + (Zqspanish) + (Znrrespc) + (Zqindian)

SoVI Lite 1 has a strong positive correlation with the $SoVI_{TR}$-SACD (R=.889, s=0.000). This version portrays less information on the tails of the distributions (e.g. fewer red areas, fewer dark blue areas). There was a 26% change in classes mostly going up or down by one rank (e.g. 1 to 2, 3 to 2). Less than 1% of the tracts jumped from the top (most vulnerable) to the bottom (least vulnerable) or the bottom to the top when using a standard deviation classification system with three classes.

In a variation on above (SoVI Lite 1), the single variable with the highest correlation coefficient for each component was used, but instead of the standardized z-scores, the raw value for these variables was used in the equation. The procedures remained the same--summing using the cardinality associated with the creation of SoVI. This test (SoVI Lite 7) has a lower correlation with $SoVI_{TR}$-SACD (R=.479, s=0.000) as well as SoVI Lite 1 (R=.560, s=0.000), and was eliminated from consideration.

SoVI Lite 4 & SoVI Lite 5: Hazards of Place Theoretical Construct

These two versions of SoVI Lite are based on the hazards of place (HOP) model of vulnerability (Cutter et al. 2000) implemented for Georgetown County, South Carolina. This study was the first attempt to develop an empirically based measure of social vulnerability to hazards and was the precursor to the development of the original SoVI metric. Eight socioeconomic indicators were used: total population, total number of housing units, total number of females, total non-white population, population under age 18, population over age 65, mean house value, and total number of mobile homes. We used two different methods for standardizing the eight input variables.

In SoVI Lite 4, a standardized ratio method was used (Cutter et al. 2000). In this procedure, each social variable was standardized by first determining the ratio of that variable in each census tract to the total number of that variable in the South Atlantic region. In Table 2, for example, the number of people over age 65 in each tract was tabulated (column 2), as was the total number of people over age 65 in the region (column 3). The ratio of the number of older persons to the total for the region was computed (column 4) This value (X) was then divided by the maximum value (X) to create an index that ranges from 0 – 1. Higher index values indicate greater vulnerability, as in Tract B (Table 2). All the social variables were standardized using this approach with the exception of mean house value. In this case, since negative numbers were possible, the absolute value of the difference between tract and county was added (Table 3). The difference between region and tract housing was computed (column 4) by taking the region average of mean house value and subtracting the mean house value for each census

tract. The absolute value of the maximum x (column 4) was added to create (Y) (column 5) to remove negative numbers. Finally, the ratio of the new value (Y) to the maximum Y generated the mean house value index (column 6).

Table 2: Calculation of SoVI Lite 4 & 5 Index Values

Census Tract	# of People Over Age 65 in Tract	# of People Over Age 65 in South Atlantic Region	Ratio of Tract to South Atlantic Region (X)	Age over 65 Vulnerability Index Value (X/maximum X)
A	76	2500	0.030	0.633
B	120	2500	0.048	1.000
C	35	2500	0.014	0.292

Table3: Calculation of SoVI Lite 4 & 5 House Value Index Value

Census Tract	Mean House Value ($) in Tract	Mean House Value ($) in South Atlantic Region	Value Difference ($) of South Atlantic Region and Tract (X)	X = Absolute Value of Maximum X (Y)	Mean House Value Vulnerability Score (Absolute value Y/ maximum Y)
A	35,321	75000	39,679	89,715	1.000
B	125,036	75000	-50,036	0	0.000
C	72,280	75000	2,720	52,756	0.588

We also assumed a simple additive model where all standardized variables were summed to create the SoVI Lite 4 score according to the following equation:

SoVI Lite 4=(population_std) + (#units_std) + (#females_std) + (#nonwhites_std) + (popovr65_std) + (mean house value_std) + (#mobile homes_std) + (popless18_std)

For SoVI Lite 5, we used a different standardization technique, z-scores (which rescaled the input variables so they have a mean of zero and a standard deviation of one). We then imposed the expected cardinality for each variable's contribution to the final score and summed. The equation for SoVI Lite 5 is:

SoVI Lite 5= (Ztot_pop) + (Ztot_units) + (Zfemales) + (Znonwhite) + (Zovr65) - (Zmean_hseva) + (Ztot_moho) + (Zless18)

There is a very weak correlation between SoVI Lite 4 and $SoVI_{TR}$-SACD (R=.111, s=.000) as well as a weak correlation between SoVI Lite 5 and $SoVI_{TR}$-SACD (R=.111, s=.000). This was the weakest fit of all our tests. The spatial patterns are significantly different as well (see Appendix 1), with 61% of the tracts changing categories, and 14% moving from low vulnerability to high vulnerability or vice-versa using a standard deviation classification system with three classes. The weaknesses in statistical and spatial replication eliminated these two metrics from further consideration.

SoVI Lite 8: Literature-Derived Theoretical Construct

Those population characteristics known to influence social vulnerability were used to construct SoVI Lite 8. Using the Heinz Center (2002) report, we selected the fourteen characteristics that were specific to social vulnerability (excluding two characteristics that represented the built environment, commercial development, infrastructure; and two others because of lack of data, population growth and health status). The fourteen variables (see technical appendix) represent the following characteristics: socioeconomic status; gender, race and ethnicity; age, employment; rural/urban; residential property; renters; occupation; family structure; education, medical services; social dependence; special needs populations. The variables were standardized using z-scores and summed based on *a priori* understanding of the directionality of the influence (Heinz Center 2002).

The correlation between SoVI Lite 8 and $SoVI_{TR}$-SACD is good (R=.695, s=0.000). Spatially, the broad patterns are similar, but there are variations within these broad bands, with less emphasis on the extremes (see technical appendix).

SoVI Lite 2 Individual Predictors

This test involved the prediction of the $SoVI_{TR}$-SACD using a stepwise linear regression model. The dependent variable was the $SoVI_{TR}$-SACD score, and the independent variables were the 32 variables (standardized) that were used to compute $SoVI_{TR}$-SACD. We fully acknowledge that this violates some of the inherent assumptions within regression analyses, but for our purpose we were interested in the relative strength of each independent variable (how much it improved the R^2) in the model, and secondly, its relative importance in that model (Beta coefficient).

The first test, SoVI Lite 2, used the regression procedure and the model generated eight variables, with an R^2 =0.832, s=0.000. These eight variables were summed without weights or cardinality using the equation below:

SOVI Lite 2=Zqpovty + Znrrespc + Zqindian + Zmigra + Zqpop65o + Zqspanish + Zmhseval + Zqfemale

As expected, there was a strong correlation between SoVI Lite 2 and $SoVI_{TR}$-SACD (R=.719, s=0.000).

SoVI Lite 3 and SoVI Lite 6 Predictors with Cardinality and Weights

To improve the explanation from SoVI Lite 2, we conducted two additional tests. The first (SoVI Lite 3) used the standardized eight variables from the regression equation, but summed them using the cardinality associated with each Beta coefficient. This resulted in one significant change to the formulation, e.g., the subtraction of median house value (reduces vulnerability).

SOVI Lite 3=Zqpovty + Znrrespc + Zqindian + Zmigra + Zqpop65o + Zqspanish - Zmhseval + Zqfemale

Here the correlation between SoVI Lite 3 and $SoVI_{TR}$-SACD was significantly improved (R=.905; s=0.000). Finally, we took the SoVI Lite 3 version, weighted each variable using its Beta coefficient, and then summed to produce and overall score (see equation below), called SoVI Lite 6. This variant produced the highest correlation (R=.912, s=0.000) of any of the tests.

*SOVI Lite 6= (Zqpovty * .323) + (Znrrespc * .279) + (Zqindian * .347) + (Zmigra * .323) + (Zqpop65o * .264) + (Zqspanish * .293) + (Zmhseval * (-.252)) + (Zqfemale * .227)*

Spatially, the patterns between $SoVI_{TR}$-SACD and SoVI Lite 3 and SoVI Lite 6 are similar (Figure 2).

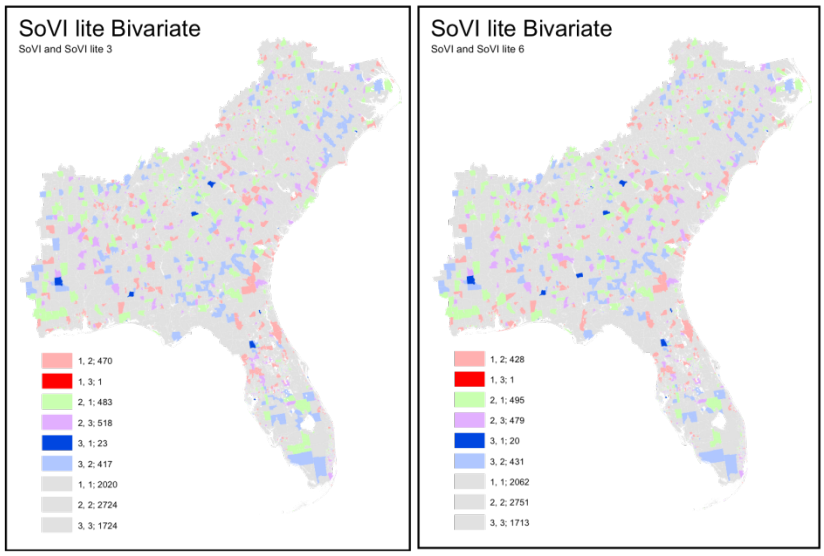

Figure 2 Spatial Comparison of $SoVI_{TR}$-SACD with SoVI Lite 3 and SoVI Lite 6 results

In both cases, more than three quarters of the census tracts did not change categories (77.2% in SoVI Lite 3; and 77.9% in SoVI Lite 6). For those tracts that did change, the vast majority shifted out of the middle range either up or down one class. Less than one percent of the tracts changed by two classes (e.g. red to dark blue or dark blue to red), or more from the original $SoVI_{TR}$-SACD.

SoVI Lite Recipe for the Southeast

The criteria for selecting the most appropriate configuration for simplifying the construction of the Social Vulnerability Index were three-fold: 1) replication of the original using a simple correlation statistic R=0.85 or better; 2) spatial similarity with more than 75% of the spatial units remaining in the same mapped category; and 3) ease of use by USACE personnel and others. Based on these criteria, the metric that best fits and the one we recommend for use in the Southeast Region is SoVI Lite 1, or $SoVI_{L}$-SACD (see equation below).

$SoVI_L$ SACD = (Zqpovty) + ABS(Zqpop65o) + ABS(Zqurban) – (Zqrich) + (Zqrenter) + (Zqfemale) + (Zqspanish) + (Znrrespc) + (Zqindian)

Where:

Zqpoverty =	% living below poverty (z-score)
Zqpop65o=	% population 65 and over (z-score)
Zqurban=	% urban population (z-score)
Zqrich=	% of households earning $100,000 or more (z-score)
Zqrenter=	% renter occupied housing units (z-score)
Zqfemale=	% female population (z-score)
Zqspanish=	% Hispanic (z-score)
Znrrespc=	per capita residents in nursing homes (z-score)
Zqindian=	% Native American (z-score)

While the best variant for SoVI Lite is SoVI Lite 1, which is easier to compute (does not require the additional regression analysis), SoVI Lite 3 provides a slight improvement in correlation with the original $SoVI_{TR}$-SACD (Pearson's R=.889 for SoVI Lite 1 versus Pearson's R=.912 for SoVI Lite 3). It also provides fewer categoric changes in ranks (77.2% no change in SoVI Lite 3 versus 74.0% no rank changes in SoVI Lite 1). Finally, the Chronbach's Alapha test of reliability shows a significant overlap between the two measures (α=.933). Further it showed that the reliability between both SoVI Lite 1 and SoVI Lite 3 and SoVITR-SACD are high as well (α=.935 for SoVI Lite 1; α=.946 for SoVI Lite 3). In other words, these versions are nearly identical.

Scalability and Transferability

To assess the robustness of the SoVI Lite, we undertook two different analyses of the ability of the SoVI Lite to downscale to a sub-county level within the region, and its application to a different region. Chatham County, Georgia was the test bed for the downscaling (regional equations to local applications) and for transferring locally derived vulnerability scores to the region.

For the first test we subset the regional SoVI Lite 1-8 and the regional $SoVI_{TR}$ scores for Chatham County, Georgia. Of the eight variants, SoVI Lite 1 and SoVI Lite 7 correlated best with $SoVI_{TR}$-Chatham County (R=.866, s=0.000 and R=.827, s=0.000 respectively). However, SoVI Lite 3 and SoVI Lite 6 still maintained their robustness and correlated well with $SoVI_{TR}$ –Chatham County (R=.784, s=0.000 and R=.810, s=0.000 respectively). In our second test, we recalculated SoVI Lite 1, 3 and 6 for Chatham County census tracts using the South Atlantic Regional equations. Again, there is a good correlation between the $SoVI_L$ SACD and the $SoVI_L$ Chatham (R=. 640, s=0.000 for SoVI Lite 1; R=.550, s=.000 for SoVI Lite 3; R=.506, s=0.000 for SoVI Lite 6). Both tests confirm that SoVI can be downscaled using both the original formulation at the tract level for the region ($SoVI_{TR}$) and the simplified version for the region ($SoVI_L$). Scaling up from the county to the region was less productive, which was not a surprise. The county level indicators were less indicative of regional trends (upscaling) and the correlation between the $SoVI_L$-Chatham and the $SoVI_L$ SACD weaker but still significant (R= 0.4768, s=0.000) (see Technical Appendix for more details on the testing). As expected, county level indicators were far less effective descriptors of vulnerability at the regional scale than vice versa. Comparing these new calculations (Chatham-specific SoVI) with the original SoVI score for the South Atlantic Region ($SoVI_{TR}$-SACD), we see

a moderate correlation when using county indicators to characterize regional patterns of vulnerability (R=-0.568, s=.000).

Transportability

A second analysis took the South Atlantic Division SoVI Lite recipe ($SoVI_L$-SACD) and applied this to a different USACE Region. Using the Mississippi Valley Division as a test bed, we performed a number of transferability tests using both $SoVI_{TR}$ and SoVI Lite metrics.

The very essence of the Social Vulnerability Index assumes that socio-economic and demographic indicators vary across space. Hence, the creation of a SoVI score for any specific level of geography will work modestly well when scaling down within that same geographic area. However, because SoVI is a place-based comparative metric, vulnerable populations within one geographic entity may not have the same set of characteristics as those vulnerable populations at a different geographic scale or focus. For example, while race and ethnicity are important components of social vulnerability, they manifest themselves quite differently. In the Southeast, the most dominant indictor of race and ethnicity is percentage African American, while in Southwest it is percentage Hispanic.

The creation of a SoVI Lite metric for the South Atlantic USACE division is a classic example of the transportability issue. While this simplified approach to determining social vulnerability correlates well with the actual social vulnerability scores at the census tract level for the South Atlantic Region (R = .905, s=0.000), when this simplified "recipe" derived for the South Atlantic Division (SA) (below)

$$SoVI\ Lite\ 1\ (SA) = \textit{(Zqpovty) + ABS(Zqpop65o) + ABS(Zqurban) – (Zqrich) + (Zqrenter) + (Zqfemale) + (Zqspanish) + (Znrrespc) + (Zqindian)}$$

was applied to the Mississippi Valley Division (MSV), the correlation was much less acceptable (R=.69, s=0.000).

To further illustrate the place-dependency of the SoVI construct, we developed a $SoVI_{TR}$ for the Mississippi Valley Division ($SoVI_{TR}$-MV), and from that a SoVI Lite version ($SoVI_L$-MV). The SoVI Lite algorithm developed specifically for the Mississippi Valley Division included three different input variables when compared to SoVI Lite for the South Atlantic ($SoVI_L$-SA). These variables were percent of the population over 25 with no high school diploma, rural farm populations as a percentage of total population, and percent of the population collecting social security benefits.

$$SoVI\ Lite\ 1\ (MV) = \textit{(Zqed12les) + ABS (zqssben) + ABS (zqrfrm) + (Zqrenter) + (Zqfemale) + (Zqspanish) + (Znrrespc) + Zqindian}$$

In other words, the poverty variable in one region becomes an education variable in the other; and age (population over 65) becomes percentage of the population receiving social security benefits.

The correlation between the $SoVI_{TR}$(MV) and the SoVI Lite 1 (MV) is not as good for (R=.730, s=0.000) as good as the correlation between SoVI Lite 3 (MV) and the $SoVI_{TR}$ (MV) (R=.895, s=0.000). In this case, the preferred simplifying variant woud be SoVI Lite 3.

While SoVI measures work and are scalable within specific geographic areas, one must use caution in the application of specific measures of SoVI or SoVI Lite when attempting to cross into different geographic space. The SoVI Lite metric developed for the USACE South Atlantic Division provides a robust measure of social vulnerability in that region, **only**.

SoVI Lite Application to Corps Planning

It is unclear whether the experimentation with developing a simplified version of the Social Vulnerability Index (SoVI) yielded a practical application for Corps personnel to conduct such analyses in the field. The SoVI Lite equation is simplified and uses nine variables, but the calibration is for the South Atlantic region only, and cannot be used in other regions. Using different configurations that do not rely initially on the full-scale construction of the Social Vulnerability Index (SoVI) such as the Hazards of Place Model (HOP) with eight variables (SoVI Lite 4 and SoVI Lite 5), or the theoretical construct of SoVI with fourteen variables (SoVI Lite 8) do not yield the same strong correlations as the other approaches. While they may be easier to implement, their ability to capture the multi-dimensional nature of social vulnerability is less than the original SoVI construct.

Conclusions

The Social Vulnerability Index (SoVI) is temporally and spatially dependent. Because SoVI is a comparative metric, the study area chosen for the analysis is a critical input variable, because all the enumeration units within that study area are relative to each other, not some objective standard. While a certain amount of downscaling to a finer level of granularity, is possible, for example from a region to a county to a sub-county in that region, the transportability of one regional representation of social vulnerability to another region is not possible unless it was calibrated for that geography as well.

SoVI Lite metric was produced for the Southeast region and should not be universally applied across all USACE regional divisions, because the SoVI Lite recipe will vary somewhat by region as a function of the differences in the social economic and demographic characteristics of the residents. This is similar to hydrology where regional equations are used to define or calibrate discharge models, for example.

To achieve a universal SoVI Lite for use in **all** USACE Divisions for planning and emergency management requires 1) either a SoVI Lite metric calibrated for the entire US, which can then applied regionally; or 2) the development of a regionally specific SoVI Lite metric for each USACE civilian planning division. The latter would produce the most detailed information, calibrated for the local differences in social vulnerability within the Division or region. Such subtle differences in social vulnerability are likely to be masked at the national level (where the population may be more heterogeneous, and will be more pronounced in a regionally specific recipe versus a national recipe. Until we conduct such national versus regional analyses, we will not know.

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Appendix D: Social Vulnerability Profile Computation

Steps for creating a Social Vulnerability Profile are listed below.

1. Obtain and create SVP variables. Download the requisite variables from the U.S. Census Data Engine and create SoVI variables. The Census American Fact Finder on-line interface provides a simple way to find and download census data at all levels of geography. Commercial products are also available that provide easier access to census data but that generally require paying a fee for access.

   The Census Bureau assigns a code to a data field such that the first letter together with the three numerals indicate a table, while the next three numerals indicate a column in that table. The code P012025, for example, means that the data will be found in Table P12, data column 25. When searching for tables by table number at the web site, the researcher should omit leading zeroes. Enter P12 to find the table that contains variable P012025. Table D1 shows the SoVI variables and their location in U.S. Census data tables and the formulas to create them. For example, to create the variable "Percent of population 65 or older" requires the computation and summing of a number of sub-variables: males 65 and 66, 67 to 69, 70 to 74, 75 to 79, 80 to 84, and 85 and over; as well as the same sub-variables for females, divided by the total population and multiplied by 100.

2. Verify the accuracy of data obtained by using descriptive statistics such as the minimum and maximum values. Check for missing values for the unit of analysis. If some cells have a missing value, substitute the mean value for the variable in its place. The computation of a large number of variables is time consuming and tedious work that can result in errors. Patience and checking work are necessary.

Table D1. Example Social Vulnerability Profile variables showing census source and equation.

Vulnerability factor	Potential indicator variables	Source	Equation
Low Income/ Poverty Level	Percent of population living below poverty level 2000	SF3, Table P87: Poverty Status in 1999 by Age SF1, Table P1: Total Population	P87/P1
Elderly/Young	Percent of population ≥65 years of age 2000 Percent of population <5 years of age 2000	SF1, Table P12: Sex by Age	P12/P1
Disabled	Disability status	SF3, Table P42: Disability Status by Employment Status for the Civilian Noninstitutionalized Population 5 Years and Older	
Female-headed Households	Percent female-headed households, no spouse present 2000	SF1, Table H17: Tenure by Household Type (Including Living Alone) by Age of Householder	
Minorities	Nativity Proportion of minority residents Proportion of foreign born	SF3, Table PCT12: Nativity by Language Spoken at Home by Ability to Speak English for the Population 5 Yrs. And Older	
Occupants of Mobile Homes/ Renters	Percent of housing units that are mobile homes 2000 Percent renter-occupied housing units 2000	SF3, Table HCT3: Tenure by Household Size by Units in Structure (Occupied Housing Units) SF1, Table H4: Tenure SF1, Table H1: Housing Units	H4/H1
Transient/ Homeless	Homeless persons 2000*	SF1, Table QT-P12: Group Quarters Population by Sex, Age, and Type of Group Quarters	

*Total count of persons living in homeless shelters on a designated night (March 27, 2000), people receiving free meals at soup kitchens at a designated time on March 28, 2000, and people found living at designated street locations on March 29, 2000.

3. Normalize the input variables through the creation of z-scores with a mean of 0 and a standard deviation of 1. Use the Standardize function in Excel to generate the normalized distribution of scores for each variable. Excel functions used in creating the SoVI data file are shown in Table D2.

Table D2. Excel functions used in Social Vulnerability Profile analysis.

Excel function	Application in SoVI analysis
ABS	Absolute value
AVERAGE	Mean, used in calculating Z values
STDEV	Standard deviation, used in calculating Z values
STANDARDIZE	Calculate Z values

Table D3 shows the spreadsheet computations for deriving z-scores for Elderly, Young, Disabled, and Homeless variables used in the Chatham County, GA, SVP example.

Table D3. Computations for total population, elderly, young, disabled, and homeless, Chatham County, GA, census tracts.

Census Tract	Total Population	Percent of Population >= 65 2000	Z-Score Pop >= 65	Percent of Population Under 5 yrs 2000	Z-Score Pop Under 5	Total Population (Sampled)	Total w/ Disability	Percent Disabled	Z-Score Pop w/ Disabilities	Homeless	Z-Score Homeless
Census Tract 1, Chathan	1,215	1.48%	-1.8	18.1%	4.1	862	270	31.3%	0.9	72	1.2
Census Tract 3, Chathan	2,205	6.26%	-1.1	1.7%	-1.8	2,157	390	18.1%	-0.7	199	4.0
Census Tract 6.01, Chatl	4,034	18.22%	0.9	8.9%	0.8	3,713	1176	31.7%	0.9	0	-0.3
Census Tract 8, Chathan	797	9.41%	-0.5	2.5%	-1.5	735	77	10.5%	-1.5	0	-0.3
Census Tract 9, Chathan	1,246	26.16%	2.2	2.1%	-1.7	1,175	194	16.5%	-0.8	50	0.7
Census Tract 11, Chatha	2,322	8.35%	-0.7	7.9%	0.4	1,933	626	32.4%	1.0	8	-0.2
Census Tract 12, Chatha	1,336	12.05%	-0.1	10.9%	1.5	1,180	371	31.4%	0.9	0	-0.3
Census Tract 13, Chatha	1,030	4.85%	-1.3	4.1%	-1.0	1,032	168	16.3%	-0.9	3	-0.3
Census Tract 15, Chatha	1,224	10.54%	-0.4	2.8%	-1.4	1,154	310	26.9%	0.4	3	-0.3
Census Tract 18, Chatha	1,000	11.30%	-0.2	6.7%	0.0	958	225	23.5%	0.0	9	-0.2
Census Tract 19, Chatha	1,106	8.32%	-0.7	6.6%	0.0	941	201	21.4%	-0.3	11	-0.1
Census Tract 20, Chatha	1,860	12.47%	0.0	6.9%	0.1	1,687	572	33.9%	1.2	0	-0.3
Census Tract 21, Chatha	2,429	13.54%	0.1	6.3%	-0.1	2,383	783	32.9%	1.1	0	-0.3
Census Tract 22, Chatha	4,617	11.59%	-0.2	8.2%	0.5	4,202	1148	27.3%	0.4	0	-0.3
Census Tract 23, Chatha	2,208	17.53%	0.8	7.0%	0.1	2,076	695	33.5%	1.1	0	-0.3
Census Tract 24, Chatha	1,276	15.05%	0.4	7.3%	0.2	1,192	291	24.4%	0.1	0	-0.3
Census Tract 25, Chatha	1,008	25.00%	2.0	4.8%	-0.7	911	434	47.6%	2.8	39	0.5
Census Tract 26, Chatha	1,670	11.02%	-0.3	5.9%	-0.3	1,582	532	33.6%	1.2	31	0.3
Census Tract 27, Chatha	3,404	12.49%	0.0	5.9%	-0.3	3,232	1217	37.7%	1.6	0	-0.3
Census Tract 28, Chatha	3,086	15.68%	0.5	7.2%	0.2	2,868	906	31.6%	0.9	0	-0.3
Census Tract 29, Chatha	3,024	17.23%	0.7	6.2%	-0.2	2,842	478	16.8%	-0.8	0	-0.3
Census Tract 30, Chatha	1,965	14.10%	0.2	6.2%	-0.2	1,817	382	21.0%	-0.3	4	-0.3
Census Tract 32, Chatha	1,111	15.30%	0.4	7.8%	0.4	1,054	300	28.5%	0.6	0	-0.3
Census Tract 33.01, Cha	1,995	21.45%	1.4	6.0%	-0.3	1,925	623	32.4%	1.0	0	-0.3
Census Tract 33.02, Cha	1,851	18.15%	0.9	3.8%	-1.1	1,688	496	29.4%	0.7	0	-0.3
Census Tract 34, Chatha	4,477	22.83%	1.6	5.1%	-0.6	4,188	1114	26.6%	0.3	0	-0.3
Census Tract 35.01, Cha	2,909	13.51%	0.1	7.7%	0.4	2,691	798	29.7%	0.7	22	0.1
Census Tract 35.02, Cha	3,820	15.68%	0.5	6.9%	0.1	3,562	885	24.8%	0.1	0	-0.3
Census Tract 36.01, Cha	3,000	10.97%	-0.3	8.7%	0.7	2,616	567	21.7%	-0.2	0	-0.3
Census Tract 36.02, Cha	5,170	10.87%	-0.3	7.4%	0.2	4,893	1188	24.3%	0.1	29	0.3
Census Tract 37, Chatha	1,738	10.24%	-0.4	7.4%	0.3	1,646	486	29.5%	0.7	6	-0.2
Census Tract 38, Chatha	2,860	7.76%	-0.8	7.2%	0.2	2,542	810	31.9%	1.0	13	-0.1
Census Tract 39, Chatha	4,003	16.29%	0.6	7.2%	0.2	3,603	982	27.3%	0.4	8	-0.2
Census Tract 40.01, Cha	4,515	25.03%	2.0	5.7%	-0.4	4,203	973	23.2%	-0.1	4	-0.3
Census Tract 40.02, Cha	3,891	18.74%	1.0	5.4%	-0.5	3,443	723	21.0%	-0.3	29	0.3
Census Tract 41, Chatha	2,066	14.42%	0.3	5.2%	-0.5	1,904	403	21.2%	-0.3	0	-0.3
Census Tract 42.02, Cha	8,312	8.41%	-0.7	7.4%	0.3	7,536	1138	15.1%	-1.0	13	-0.1

Census Tract 42.05, Cha	9,888	12.98%	0.0	5.5%	-0.4	9,023	1535	17.0%	-0.8	5	-0.2
Census Tract 42.06, Cha	1,693	6.67%	-1.0	8.2%	0.5	1,745	271	15.5%	-0.9	6	-0.2
Census Tract 42.07, Cha	3,429	11.58%	-0.2	9.5%	1.0	3,073	753	24.5%	0.1	38	0.5
Census Tract 42.08, Cha	5,418	10.35%	-0.4	8.0%	0.5	4,747	861	18.1%	-0.6	0	-0.3
Census Tract 43, Chatha	2,981	5.94%	-1.1	8.2%	0.5	614	27	4.4%	-2.2	0	-0.3
Census Tract 44, Chatha	1,989	9.70%	-0.5	7.7%	0.4	1,752	627	35.8%	1.4	0	-0.3
Census Tract 45, Chatha	3,895	16.35%	0.6	5.6%	-0.4	3,755	988	26.3%	0.3	52	0.8
Census Tract 101.01, Ch	2,084	5.76%	-1.1	16.6%	3.6	1,831	487	26.6%	0.3	1	-0.3
Census Tract 101.02, Ch	3,738	15.14%	0.4	6.1%	-0.2	3,403	616	18.1%	-0.6	20	0.1
Census Tract 102, Chath	4,209	12.71%	0.0	6.9%	0.1	3,855	1019	26.4%	0.3	314	6.5
Census Tract 105.01, Ch	4,720	5.93%	-1.1	5.9%	-0.3	3,177	1229	38.7%	1.7	0	-0.3
Census Tract 105.02, Ch	3,103	8.22%	-0.7	8.2%	0.5	2,896	620	21.4%	-0.3	0	-0.3
Census Tract 106.01, Ch	5,685	11.66%	-0.2	8.3%	0.6	5,214	1329	25.5%	0.2	4	-0.3
Census Tract 106.03, Ch	1,848	14.07%	0.2	6.9%	0.1	1,700	315	18.5%	-0.6	0	-0.3
Census Tract 106.04, Ch	1,126	13.77%	0.2	11.6%	1.8	908	368	40.5%	2.0	0	-0.3
Census Tract 106.05, Ch	0	0.01%	-2.1	0.1%	-2.4	0	0	0.1%	-2.7	0	-0.3
Census Tract 107, Chath	4,484	13.58%	0.1	4.7%	-0.7	3,051	789	25.9%	0.3	0	-0.3
Census Tract 108.01, Ch	2,537	10.72%	-0.3	7.4%	0.3	2,360	534	22.6%	-0.1	0	-0.3
Census Tract 108.02, Ch	2,220	8.78%	-0.6	6.3%	-0.1	2,108	510	24.2%	0.1	13	-0.1
Census Tract 108.03, Ch	6,080	9.70%	-0.5	7.3%	0.2	5,558	1021	18.4%	-0.6	0	-0.3
Census Tract 108.04, Ch	8,331	6.41%	-1.0	8.0%	0.5	7,498	1558	20.8%	-0.3	0	-0.3
Census Tract 108.05, Ch	9,241	3.83%	-1.5	8.4%	0.6	7,894	960	12.2%	-1.3	0	-0.3
Census Tract 109.01, Ch	3,652	11.83%	-0.2	7.4%	0.3	3,237	715	22.1%	-0.2	0	-0.3
Census Tract 109.02, Ch	1,170	16.92%	0.7	4.4%	-0.9	1,081	159	14.7%	-1.0	0	-0.3
Census Tract 110.02, Ch	6,958	39.09%	4.3	2.0%	-1.7	6,878	762	11.1%	-1.5	2	-0.3
Census Tract 110.03, Ch	6,161	10.78%	-0.3	6.3%	-0.1	5,709	822	14.4%	-1.1	61	1.0
Census Tract 110.04, Ch	3,767	14.07%	0.2	6.1%	-0.2	3,524	398	11.3%	-1.4	0	-0.3
Census Tract 111.01, Ch	7,952	10.32%	-0.4	6.2%	-0.2	7,424	1116	15.0%	-1.0	0	-0.3
Census Tract 111.03, Ch	3,696	19.05%	1.0	3.2%	-1.3	3,464	713	20.6%	-0.4	25	0.2
Census Tract 111.04, Ch	4,888	9.31%	-0.6	6.1%	-0.2	4,561	861	18.9%	-0.6	0	-0.3
Census Tract 111.05, Ch	9,325	9.66%	-0.5	6.7%	0.0	8,637	1128	13.1%	-1.2	0	-0.3
Total	232,048										
Mean		12.75%		6.72%				23.7%		16.1	
SD		6.14%		2.77%				8.6%		46.2	

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14. ABSTRACT

Social effects have long been part of water resources planning in the United States. The experiences of Hurricanes Katrina, Rita, and Ike, as well as extensive flooding in the Upper Midwest, have again emphasized to the Nation the reality and significance of the social impacts of floods. One of the lessons of Katrina and Rita has been that the social effects on socially vulnerable populations have been woefully overlooked and underestimated. While all people living in flood hazard areas are vulnerable, the social impacts of hazard exposure often fall disproportionately on the most vulnerable people in a society—the poor, minorities, children, the elderly, and the disabled. These groups often have the fewest resources to prepare for a flood, live in the highest-risk locations in substandard housing, and they lack the knowledge or social and political connections necessary to take advantage of resources that would speed their recovery. This paper presents two practical methods for identifying socially vulnerable groups and illustrates how the information they provide about social vulnerability, the drivers of vulnerability, and their spatial distribution in flood hazard zones can be used in the planning process to assist in identifying problems and opportunities, developing planning objectives, creating and evaluating management measures, and evaluating project alternatives. The two Social Vulnerability Analysis methods described are the Social Vulnerability Index and Social Vulnerability Profiling. Methods and procedures are illustrated using a hypothetical study area in Chatham County, GA, as an example.

15. SUBJECT TERMS
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