SEHIC Climate Change Workgroup
Literature Review on Vulnerability to Flooding
March 1, 2008

REVIEW NOTES AND HIGHLIGHTS

The papers in this review were identified mainly from an online search using EBSCOHost Research Databases and also a Google search. The search method was more fluid and interactive, rather than a formally defined process.

Some papers identified in this search report on original flooding vulnerability research. Other papers are flood-specific, but are not original research. Instead, the papers review the literature or offer general discussions of vulnerabilities without specific references to original research. In addition, many of the papers discuss climate change and extreme weather events in general (not flood-specific).

In general, "vulnerability" and "risk" are not clearly differentiated or consistently used in much of the literature. Two papers in particular, Barnard (2001) and Sarewitz (2003), discuss the differences and offer definitions of these terms. Some papers concern risk or vulnerability to a flooding *event*, rather than specifically about risk or vulnerability to the *health impacts* of floods. Although information about populations and areas that are most vulnerable or at risk of flood events is an important component in health impacts risk and vulnerability assessments, Barredo 2007 notes that people who live in areas that have experienced little or no flooding in the past are often more vulnerable to health impacts because they are less prepared and less experienced in dealing with floods.

Overall, the review demonstrates that:

- Much more research needs to be conducted to identify population vulnerabilities to flooding.
- Researchers have developed some varied risk and vulnerability assessment methods, and most included in this review use a GIS application. (see Vescovi et al 2005 for a well-defined method of measuring a social vulnerability index.)
- The links between climate change, flooding and health impacts are unclear or have not been established in published research literature.

The remainder of this document is organized in two sections. The first section includes summary tables that list key points from the literature and the papers that indicate these results. The second section contains the full annotated bibliography.

Please direct questions or comments to Amber Sinclair, SEHIC technical consultant, at ambersin@uga.edu.

LITERATURE REVIEW SUMMARY TABLES

Notes about these tables: Bolded references indicate original research (non-bolded references are review articles, commentaries or other). Only the first author and year are listed in the tables. Please see the annotated bibliography for complete citations and reference summaries. Note that most, but not all papers in the bibliography are referenced in these tables. The papers that are not referenced offered something useful to the topic, but did not identify specific vulnerability factors or methods.

Populations with increased risk or vulnerability to health impacts of flooding:

Population:	**References:**
Men	Ahern 2005-deaths; **Ashley 2008**-deaths
Elderly	Ahern 2005-elderly comprise majority of those drowning in own home; **Gabe 2005**
Those living in places with poor infrastructure	Ahern 2005-deaths
Those with limited economic resources	Ahern 2005-deaths; **Guidry 2005**-flooding in low income associated with majority Black schools and elevated risk of respiratory illness; **Gabe 2005**-poor closely associated with being African American in New Orleans
Ages 10-19, twenties, and over 60	Ashley 2008-deaths; Penning-Roswell 2005-age over 75
Higher levels of pre-flood depressive symptoms	Ahern 2005-depression and anxiety
Lower socio-economic status	Ahern 2005-depression and anxiety; **Fielding 2005**
Women	Ahern 2005-PTSD
Over 35 years of age	Ahern 2005-PTSD
People who are rarely or never previously affected by flooding	Barredo 2007
People who live closer to a river or coast	Penning-Roswell 2005
Disabled	**Gabe 2005**-used 2000 census disability estimates to compare to areas affected by Hurricane Katrina

Populations or factors associated with increased risk or vulnerability to health impacts of climate change events in general (not flood-specific):

Population:	**References:**
Those living in coastal and other vulnerable zones	Balbus; McMicheal 2006
Older populations	Bernard 2001; Ebi 2006-over 65 years of age
Younger populations	Bernard 2001; Ebi 2006-under 1 year of age
The immunocompromised	Bernard 2001; Ebi 2006
Those with chronic diseases	Ebi 2006
Those receiving drug treatment	Ebi 2006
The obese	Ebi 2006
The poor	Bernard 2001; Colten 2006-vulnerability among the poor is due to immobility; Ebi 2006-poverty reduces response capacity; WHO 2003-income levels and distribution
For future events: children today and future generations	Balbus
Immobility (lack of transportation)	Colten 2006-related to poverty; GAO 2006-transportation disadvantaged including those in nursing homes and hospitals, low-

	income, disabled, and those with no car
Population dense areas	WHO 2003; Bernard 2001; Chakraborty 2005-total pop, number of housing units, number of mobile homes
Areas with less economic development	Chakraborty 2005-pop below poverty level, occupied housing units with no telephones, occupied housing units with no vehicles
Less food availability	WHO 2003
Local environmental conditions	WHO 2003; Bernard 2001; Carter 2005- Level of physical protection provided dams and levees
Quality and availability of public health care/infrastructure	WHO 2003; Bernard 2001
Pre-existing health status	WHO 2003; Bernard 2001
Level of technology development	Bernard 2001
Interdependence of communities	Pezzoli 2007
Those with special evacuation needs	Chakraborty 2005-institutionalized populations in group quarters, population aged 5 or younger or over age 85, population with disabilities

Risk and vulnerability assessment methods:

Method:	**References:**
Risk mapping/GIS	**Barredo 2007**-exposure, vulnerability (GDP per capita), and hazard; **Chakraborty 2005-**compares spatial distribution of risk and vulnerability; **Guidry 2005-**overlayed satellite images with school location maps; **Penning-Roswell 2005-**map risk of death and serious injury, use area-vulnerability scores based on how far people live from a river or coast; Pezzoli 2007-demonstrate mapping using EHS Portal; Fielding 2005-overlay at-risk areas and at-risk populations; **Forte 2006**; **Vescovi 2005**
Identifying, classifying and mapping flood disasters	**Barredo 2007; Sinigalliano 2007-**uses satellite imagery of flood waters in New Orleans;
Developing a social vulnerability index	**Chakraborty 2005-**based on several measures of population and structure, differential access to resources, and populations with special evacuation needs; **Vescovi 2005**
Modeling relationships to flooding	**Pielke 2000-**used regression analysis to look at associations between precipitation and flooding damage;
Modeling of flood injuries and deaths	**Zhai 2006-**injuries and deaths as a function of number of damaged buildings
Comparing at-risk populations with at-risk areas	**Fielding 2005**
In-depth study of flood victims and areas	**Khandlhela 2006-**South Africa study

ANNOTATED BIBLIOGRAPHY

Ahern M, Kovats RS, Wilkinson P, Few R, Matthies F. Global health impacts of floods: epidemiologic evidence. *Epidemiol Rev* 2005; 27:36-46.

A review of epidemiological studies of health impacts of flooding in all regions of the world. Review results are presented in six main categories: mortality, injuries, fecal-oral disease, vector-borne disease, rodent-borne disease, mental health, and other health outcomes. A table is also presented that lists main results for each paper reviewed (seven studies from U.S.). This review is mainly concerning evidence of health outcomes, but includes some limited information regarding risk and vulnerability:

- Deaths: limited information on risk factors, but men appear more at risk than women, and the elderly account for most of persons drowning in their own homes; risk is also higher where infrastructure is poor and economic resources are limited.
- Injuries: little information on injuries from floods, and the authors do not comment on risk and vulnerability for injury.
- Mental health: increases in depression and anxiety, especially in persons with higher levels of preflood depressive symptoms and those from lower socioeconomic groups. Some studies show PTSD symptoms are worse in women and those over age 35; however these studies rely on self-reports of flood experiences and so are subjective.

Ashley S, Ashley WS. Flood fatalities in the United States. *J Applied Meteorology and Climatology* 2008. *(in press)*.

Three main types of flash flooding: coastal flooding, flash flooding, and river flooding. This is the first study to construct a database of all flood fatalities in the U.S. from 1959-2005. The results indicate social vulnerabilities and physical vulnerabilities. A total of 4,586 fatalities over the 47 year period. June, July and August are high fatality months. Identified ages 10-19, twenties and greater than 60 years as most vulnerable to death from flooding, although the authors acknowledge that 63% of data had unknown age and 49% had unknown gender. The majority with known gender were male. High fatality states (standardized by population) are South Dakota, Montana, Mississippi and West Virginia. The paper shows maps of the U.S. with fatality counts by state, and includes a table of fatality and injury stats by state, including type of event (flash flooding, coastal flooding, river flooding). One limitation of this paper may be the data source – Storm Events – which has been shown to underestimate fatalities.

Balbus JM, Wilson ML. Human health & global climate change: a review of potential impacts in the United States. Pew Center on Global Climate Change.

This review is organized by type of health outcome. Distinguishes between vulnerability (ability of a population to adapt or protect itself) and sensitivity (where severity of an outcome responds to changes in climate). They use the example of heat-associated mortality as a sensitivity, and differences in separate populations (such as wealthy and poor) as a vulnerability. The authors note no published studies have modeled health consequences of extreme events as they relate to climate change. One way that researchers estimate how climate change will affect human health is by looking at the associations of climate variability and health. In general, populations at risk from extreme weather events include those living in coastal and other vulnerable zones. The authors emphasize that caution must be taken when interpreting studies that use space (i.e., comparing geographic regions and interpolating health outcome results between them based on static climate data) as a substitute for time. Need to also consider that many of those most affected by future changes in climate are children today and future generations.

Barredo JL, de Roo A, Lavalle C. Flood risk mapping at European scale. *Water Science & Technology* 2007; 56:11-17.

Presents a method for flood risk mapping based on exposure, vulnerability and hazard. In a two-paragraph section (pg. 15) on vulnerability, it is noted that people affected regularly by floods are less vulnerable to floods than groups having a similar socio-economic condition but who have never or rarely been affected by a flood. Also the authors argue that vulnerability is "without doubt" the most complex component of flood risk. Studies at a very local level require detailed information about people, households, and communities. Behavioral information is also needed. For large scale studies, the authors reference Dilley et al 2005 in noting that general proxies are the most to be hoped for in vulnerability assessment. The authors use the only proxy available for the entire EU in their study – GDP per capita (assumption that poorest regions are least prepared).

Barredo JI. Major flood disasters in Europe: 1950-2005. *Natural Hazards* 2007; 42:125-148.

Historic data on flood losses and casualties are not standardized or comprehensive. The purpose of this paper is to identify, classify, and map the major flood disasters over a 56-year period in the EU. Data sources are the Emergency Events Database (EM-DAT) (from Centre of Research on Epidemiology of Disasters in Brussels (CRED) and United States Office for Foreign Disaster Assistance (OFDA)) and NATHAN of Munich Re, as well as other sources. Barredo cautions that increasing damage statistics are due to several factors, including socioeconomic, political and environmental. Also, flood damage data reporting has increased and improved. Not a lot here about vulnerability, as this paper focuses on major flood event trends.

Bernard SM, Ebi KL. Comments on the process and product of the Health Impacts Assessment component of the National Assessment of the Potential Consequences of Climate Variability and Change for the United States. *Environ Health Perspect* 2001; 109:177-184.

Provides a descriptive overview of the health impacts assessment of the National Assessment of climate change impacts. Analysis of population vulnerabilities and adaptation were included in the assessment for each health outcome. Defines vulnerability of a population as "the extent to which health, or the natural or social systems that affect health, are sensitive to changes in climate; the capacity of the population to adapt to new climate conditions; and exposure to the climate-related hazard." Vulnerabilities to a health risk include population density, level of economic and technological development, local environmental conditions, health status, and quality and availability of health care and public health infrastructure. Emphasizes the complexity in estimating vulnerability over longer time periods due to increased uncertainty. In general, populations most vulnerable to health impacts of climate change are the very old, the very young, the immunocompromised and the poor.

Carter NT. Flood risk management: federal role in infrastructure. CRS Report for Congress, October 26, 2005.

Report about federal efforts to manage flood hazards. Includes an analysis of flood risk as a composite of flood threat, consequence and vulnerability. However, vulnerability here only refers to level of physical protection provided by dams and levees. Concerns benefit-cost analysis and federal appropriations for infrastructure. Not a lot here that seems directly relevant to SEHIC indicator development, but this provides information on what federal government is doing to mitigate the effects of disasters.

Chakraborty J, Tobin GA, Montz BE. Population evacuation: assessing spatial variability in geophysical risk and social vulnerability to natural hazards. *Natural Hazards Review* 2005; 6:23-33.

This research paper deals with the estimation of geophysical risk and socioeconomic vulnerability. It compares the spatial distribution of risk and vulnerability, and the effect of changing variables on vulnerability and evacuation plans. Uses a case study approach of a coastal area in Florida. Includes an informative review of some other studies that measured risk and vulnerability or have integrated the two measures. Notes that most vulnerability research has

looked at hazard of place. The authors modify previous work to develop a social vulnerability index for identifying evacuation needs, based on the following measures:

- Population and Structure: Total population, Number of housing units, Number of mobile homes
- Differential access to resources: Population below poverty level, Occupied housing units with no telephones, Occupied housing units with no vehicles
- Population with special evacuation needs: Institutionalized population in group quarters, Population age 5 years or under, Population age over 85 years, Population (age over 5 years) with disabilities

Step-by-step instructions are included for their methods.

Colten CE. Vulnerability and place: flat land and uneven risk in New Orleans. *American Anthropologist* 2006; 108:731-734.

Must consider biophysical (topographic) and sociocultural elements of vulnerability. Those with fewest resources live in least desirable and lowest elevation locations. Vulnerability among the poor due to immobility. For Hurricane Katrina, topographic vulnerability was spread across race and income groups, while vulnerability due to immobility was concentrated among the poor.

Curtis A, Mills JW, Leitner M. Katrina and vulnerability: the geography of stress. *J Health Care for the Poor & Underserved* 2007; 18:315-330.

This paper views vulnerability in terms of site (the proximity of a neighborhood to a hazard) and situation (the social context of that neighborhood). The paper uses a site and situation approach to show how maps of the five main sources of disaster-related stress in New Orleans can be used to predict where counseling resources should be targeted. The five types of geographic stress which are mapped and overlaid are: experiencing the storm, evacuation and relocation, pre-Katrina (involves mapping vulnerable neighborhoods –like high crime- prior to a disaster), pre-Katrina health outcomes stress, and rebound and recovery. The authors draw on their experience working as part of the LSU team providing geospatial support to Louisiana state offices during Katrina and Rita. Common health problems seen in the disaster shelters included diabetes, hypertension and gout. Neighborhood pre-conditions such as poor birth outcomes can also contribute to a higher stress load during an extreme weather event.

Ebi KL, Kovats RS, Menne B. An approach for assessing human health vulnerability and public health interventions to adapt to climate change. *Environ Health Perspect* 2006; 114:1930-1934.

Health impacts depend on vulnerability of a population and its capacity to respond, and vulnerability is a function of sensitivity, exposure, and adaptation. This paper describes 7 steps for a vulnerability and adaptation assessment, beginning with determining the scope of the assessment. One useful measure is to calculate the proportion of a disease burden that is attributable to a weather or climate event (such as deaths caused by floods). Since the focus of this paper is on describing the steps of an assessment, there is not a lot of information on specific vulnerabilities in this paper.

Ebi KL, Mills DM, Smith JB, Grambsch A. Climate change and human health impacts in the United States: an update on the results of the U.S. National Assessment. *Environ Health Perspect* 2006; 114:1318-1324.

Notes the need to focus on U.S. literature in their review to limit sources of uncertainty. More vulnerable to climate change: under 1 year and over 65 years of age, immunocompromised, those with chronic diseases or receiving drug treatment, poverty, obesity. Poverty reduces capacity to respond to changing conditions, and is often associated with climate-sensitive health outcomes. The authors looked at population projections and public health trends to assess potential future

changes in population vulnerability. For example, a larger and relatively older U.S. population will increase vulnerability in the future.

Few R, Ahern M, Matthies F, Kovats S. Floods, health and climate change: a strategic review. Tyndall Centre for Climate Change Research, Working Paper 63. November 2004.

This 138-page working paper out of the U.K. is a report of a review of over 450 academic and non-academic (including governmental reports) from around the world. Notes the need for risk communication to vulnerable populations. Refers to coping capacity as the converse of vulnerability. These are the same authors as the Ahern et al paper at the beginning of this review. In the Ahern et al paper, results of the epidemiologic review are presented, whereas this full-report includes other sections.

Fielding J, Burningham K. Environmental inequality and flood hazard. *Local Environment* 2005; 10:379-395.

A study of the social distribution of risk of flooding in England and Wales. The authors argue that vulnerability should be considered in both absolute terms of loss of life and property as well as relative terms for different groups within society. Populations at-risk were compared with populations considered not at-risk using modeling and socio-demographic data. Social classes (occupation of head of household) within a flood plain were compared by using an odds ratio measure (the "comparative environmental risk index). At-risk *areas* were identified by use of flood plain maps, while at-risk *populations* were identified through two different methods for comparison: one using census districts and the other using surface population models that redistribute the population over a grid (200m) surface. The census method showed that higher social classes are most likely to be exposed to flood hazard, while the grid method found that lower social classes are most at risk. The authors believe the grid method is more accurate, as the smaller aggregations of data result in a more accurate distribution of characteristics. The authors caution against over-reliance on mapping in research and action on vulnerability to flooding, as mapping is just one tool in developing a comprehensive understanding.

Forte F, Strobl RO, Pennetta L. A methodology using GIS, aerial photos and remote sensing for loss estimation and flood vulnerability analysis in the Supersano-Ruffano-Nociglia Graben, southern Italy. *Environmental Geology* 2006; 50:581-594.

Vulnerability here refers to agriculture, houses, and greenhouses that are most vulnerable to floods. Human health vulnerability is not included, but the methods presented here might be useful as an example of combining GIS, aerial photos and remote sensing data. The distribution of types of agriculture at risk is assessed in determining vulnerability.

Gabe T, Falk G, McCarty M. Hurricane Katrina: social-demographic characteristics of impacted areas. CRS Report for Congress, November 4, 2005.

Estimates that 700,000 or more people were acutely impacted by Hurricane Katrina. This report presents estimates of the number and characteristics of people, households and families in 2000 who lived in areas that suffered damage or flooding from Katrina in 2005. Especially impacted were the poor and African Americans in New Orleans. Specific estimates presented: 30% lived below 1 ½ times the poverty level, 44% of storm victims were African American, 88,000 elderly aged 65 and older and 183,000 children were displaced. Disabilities were a big issue, with about half of people living in affected areas reporting a disability (including mental) in the 2000 census. Also looked at labor force participation. The report graphics show how poverty rates in impacted areas compare to surrounding areas. Includes a methodology appendix, which might be a helpful reference for SEHIC. This report includes a lot of statistics, tables and charts, in several different socio-demographic topic areas to consider in determining population vulnerabilities.

Galea S, Nandi A, Vlahov D. The epidemiology of post-traumatic stress disorder after disasters. *Epidemiol Rev* 2005; 27:78-91.

This is a review of studies conducted from 1963 through 2001 that explicitly assessed PTSD following disasters, with results discussed separately for human-made and natural disasters. The most important risk factor for PTSD following a disaster appears to be the extent of exposure. For example, people who are directly injured during the disaster are most at risk of developing PTSD. Based on the literature, a plausible range of occurrence of PTSD in direct victims of disaster is 30 to 40 percent. Also at higher risk of PTSD following disasters: women, persons with preexisting or concurrent psychiatric conditions and persons who have previously experienced traumatic events or substantial stressors; people with low social support. On the other hand, other factors such as race and ethnicity, and socio-economic status are less clear, according to the authors. Several important limitations (some are common issues in studying mental health-related issues in general) are noted in this review for identifying and studying PTSD in disaster victims (e.g., assessment instruments, locating and accessing victims, etc). Several flood papers are included in the references, but the authors make no flood-specific (or other specific disaster) conclusions. Supplemental web tables are available on the full review results.

Greenough G, McGeehin M, Bernard SM, et al. The potential impacts of climate variability and change on health impacts of extreme weather events in the United States. *Environ Health Perspect* 2001; 109:191-198.

Discusses general pathways and health effects related to extreme weather events. Provides examples of recent extreme weather-related disasters that had significant public health consequences. Midwest flooding in 1993 caused 48 deaths. Infectious disease outbreaks in disaster areas are rare in the U.S. Cited study showing increased emotional and mental health problems after disasters. Flood severity determined by poverty, surrounding infrastructure, and human factors. More people living in coastal and flood plain areas, more overgrazing and deforestation in upland areas. There is disagreement on future projections of increases in hurricanes and tornadoes in the United States. National Weather Services reports on floods in the U.S. from 1969 to 1981, 1185 deaths attributed to 32 from flash floods (average 37 deaths per flash flood), most due to drownings. Cite Malilay 1997 – over 20,000 cities and communities in the U.S. at risk for flash floods.

Guidry VT, Margolis LH. Unequal health risk: using GIS to explore hurricane-related flooding of schools in Eastern North Carolina. Environmental Research 2005; 98(3):383-389.

Used GIS to overlay a satellite image of flooded areas from Hurricane Floyd with school locations, finding that low-income schools with a majority who were Black students (who are at an elevated risk of respiratory illness) had twice the risk of flooding compared to non-low-income schools with a majority who were non-Black students. The authors state that these types of results can be used to direct remediation efforts after natural disasters.

Haines A, Kovats RS, Campbell-Lendrum D, Corvalan C. Climate change and human health: impacts, vulnerability, and mitigation. *The Lancet* 2006; 367:585-596.

This paper offers a global and general overview of human health and climate change. Key points are that the overall impacts are climate change on human health are expected to be negative, and that low income countries are particularly vulnerable to the adverse affects. Discusses the WHO's recent efforts to estimate the global burden of disease due to climate change, in terms of disability adjusted life years (DALYS) lost. Flood deaths are included as a health outcome in the epidemiological modeling. The estimates also considered future changes in disease rates due to factors such as technology advances, and changes in population size and characteristics. The analysis suggests, among other things, that the number of people killed in coastal and inland floods will increase.

Khandlhela M, May J. Poverty, vulnerability and the impact of flooding in the Limpopo Province, South Africa. *Natural Hazards* 2006; 39:275-287.

Uses survey data, interviews, site visits and focus groups in an analysis of household vulnerable from a flood in two communities in 2000. The study's main points are that socio-economic factors are the major determinant of household vulnerability, but that management of the disaster and political processes also matter. Although the setting in this study is vastly different from the United States in terms of specific population characteristics, the findings support the general conclusions that those with less economic resources are more vulnerable to flooding. Also, this study uniquely looked at household assets as measure of vulnerability. Studies in the U.S. often focus solely on financial resource measures rather than assets, when assets may also be an important factor in one's vulnerability to health impacts of flooding and other disasters.

Logue JN. The public health response to disasters in the 21st century: reflections on Hurricane Katrina. *J Environ Health* 2006; 69:9-13.

This paper offers a general discussion of public health responses to disasters and the need for increased focus of public health in preparation and training for disasters.

Madrid PA, Grant R, Reilly MJ, Redlener NB. Challenges in meeting immediate emotional needs: short-term impact of a major disaster on children's mental health: building resiliency in the aftermath of Hurricane Katrina. *Pediatrics* 2006; 117:S448-S453.

Anecdotal and chronological discussion that describes the mental health needs and response after Katrina. The paper is included in this bibliography as a potential source for identifying mental health issues as they relate to vulnerable populations.

Manuel J. In Katrina's Wake. *Environmental Health Perspectives* 2006; 114(1):A33-A39.

This narrative describes the events and public health response to Hurricane Katrina, especially water and debris hazards after the Hurricane. Results from some Katrina studies are included in the discussion.

McMichael AJ, Woodruff RE, Hales S. Climate change and human health: present and future risks. *The Lancet* 2006; 367:859-869.

This is another general review paper of health and climate change. In a short section on flooding, the authors note that the most frequent natural weather disaster, according to the EM-DAT (international disaster database) between 1992 and 2001 was flooding, which killed over 100,000 people and affected more than 1.2 billion people. Specific population vulnerabilities are not discussed, but the authors note the increased risk from flooding in coastal areas of developed countries due to more people moving to these areas. They observe that more research is needed to characterize vulnerable groups. During or soon after a flood, health impacts include injuries, communicable diseases or exposure to toxic pollutants; later impacts include malnutrition and mental health disorders.

Ohl CA, Tapsell S. Flooding and human health. *BMJ* 2000;321:1167-1168.

Flooding is predominant cause of death among natural disasters in U.S., mostly by drowning. Orthopedic injuries associated with flooding in North Carolina in 1999. Flood victims are more likely to present for skin rashes, asthma, and medical needs such as dialysis and prescriptions. Flooding is also associated with emotional trauma.

Patz JA, Olson. Climate change and health: global to local influences on disease risk. *Annals of Tropical Medicine & Parasitology* 2006; 100:535-549.

Review of climate change and health outcomes. Does not include a specific discussion of vulnerability, but the article is helpful for identifying a broad range of health effects associated with different climate change scenarious.

Patz JA, Engelberg D, Last J. The effects of changing weather on public health. *Annu. Rev. Public Health* 2000; 21:271-307.

A short floods-specific section of this review paper describes health impacts of floods as being immediate, medium or long term effects.

Penning-Roswell E, Floyd P, Ramsbottom D, Surendran S. Estimating injury and loss of life in floods: a deterministic framework. *Natural Hazards* 2005; 36:43-64. (U.K.)

Presents a 4-step risk assessment methodology for assessing and mapping risk of death or serious harm (estimating the likely annual number) from flooding: hazard identification, hazard characterization, exposure assessment and risk characterization. The final risk characterization step combines the likelihood/probability of a flood (to produce the risk source), the probabilities that people will be exposed (based on the nature/size of population present and associated probabilities of exposure), and the probabilities that those exposed will be injured or will suffer loss of life. They employ "area vulnerability scores" that assess vulnerability based on how far people live from a river or coast. They also look at presence of very old (>75) and those with disabilities or sickness. A case is presented to illustrate their methodology.

Pezzoli K, Tukey R, Sarabia H, et al. The NIEHS Environmental Health Sciences Data Resource Portal: placing advanced technologies in service to vulnerable communities. *Environ Health Perspect* 2007; 115:564-571.

Describes the National Institute of Environmental Health Sciences Portal and its role in tracking environmental hazards after disasters. The Portal combines GIS, data mining and integration, and visualization techniques. Many agencies, organizations and were several universities were involved in the development of the Portal. The authors note that the interdependence of communities is important during disasters. The Portal could serve as a national resource for tracking hazards after disasters. Includes a sample GIS application for Texas, Louisiana and Mississippi.

Pielke RA, Downton MW. Precipitation and damaging floods: trends in the United States, 1932-1997. *Journal of Climate* 2000; 13:3625-3637.

A study of trends in flooding as they related to different measures of precipitation. Data collected from National Weather Service, with stepwise regression analysis. Looked for precipitation predictors of damage, damage per capita, and damage per unit wealth. The authors found that precipitation amounts are related to flood damage levels, especially 2-day heavy rainfall (relative to average rainfall in an area) and number of wet days. However, flood damage is also related to social factors, including increasing population and wealth.

Sarewitz D, Pielke Jr R, Keykhah M. Vulnerability and risk: some thoughts from a political and policy perspective. Risk Analysis 2003; 23:805-810.

The authors discuss the differences between risk and vulnerability in the context of extreme events. Vulnerability is used to describe inherent system features that create the potential for harm but are independent of the probabilistic risk of the occurrence of an event. They also distinguish between the risk of an event (e.g., a level of hurricane) and the risk of an outcome (e.g., a dollar amount in losses). The argument they make is that vulnerability should be considered along with risk approaches in the politics and policy of extreme events: vulnerability reduction is a human rights issue while risk reduction is not.

Shapiro A, Seim L, Christensen RC, et al. Chronicles from out-of-state professionals: providing primary care to underserved children after a disaster: a national organization response. *Pediatrics* 2006; 117:S412-S415.

Describes the response of the Children's Health Fund to medically underserved children in New Orleans after hurricane Katrina. Note problems due to crowding and close quarters, improper use and lack of medications, inability to obtain care and medications for chronic diseases, acute care problems with pneumonias and skin infections. Rise in uninsured due to loss of jobs, especially Vietnamese and Hispanic workers (who also face additional language and cultural barriers). Mental health issues prevalent.

Sinigalliano CD, Gidley ML, Shibata T, et al. Impacts of Hurricanes Katrina and Rita on the microbial landscape of the New Orleans area. *Proceedings of the National Academy of Sciences Journal* 2007. 104:9029-9034.

This paper describes and presents scientific study findings that show fecal indicator microbe concentrations in floodwaters in New Orleans from Hurricanes Katrina and Rita returned to pre-hurricane concentrations within 2 months of flooding. Both flooded and non-flooded areas exhibited elevated levels of fecal indicator bacteria. Evidence also suggests that fecal indicator bacteria observed in the sediment were from human fecal sources. The paper includes satellite imagery that shows flood waters. Epidemiologic studies are needed to evaluate the human health effects of sediments deposited by floodwaters. Included in this bibliography as a reference for flood water hazards.

United States Government Accountability Office. Disaster Preparedness: Preliminary Observations on the Evacuation of Vulnerable Populations due to Hurricanes and Other Disasters. Testimony before the Special Committee on Aging, U.S. Senate. May 18, 2006.

A discussion of planning efforts for evacuation of transportation-disadvantaged populations (focus on seniors) in emergency situations, including those in nursing homes and hospitals, low-income, and those with disabilities and those who do not own or operate a car. GAO interviewed state officials in areas affected by hurricanes in recent years, as well as other agency and organization representatives. Notes that identifying the size, location and composition of these transportation-disadvantaged populations in advance of an emergency can be difficult.

Vescovi L, Rebetez M, Rong F. Assessing public health risk due to extremely high temperature events: climate and social parameters. *Climate Research* 2005; 30:71-78.

This paper is about heat events, but the methods seem like they could be useful for other types of extreme weather events, including flooding. The research integrates climate variables and socio-economic measures in a GIS analysis, creating maps of estimated and future health risk. Climate hazard was comprised of two indices, while social vulnerability included 4 indices (which they call "sub-indices"): frequency of people over age 65 (age index), frequency of low-income earners (the poverty index), frequency of single-person households (the social isolation index), and frequency of people older than 20 with less than 13 years of education (the education index). An aggregated social vulnerability index is created by centering each sub-index and summing them all. The climate and social measures were then combined using a weighted method in GIS. Risk maps are presented.

World Health Organization. Climate Change and Human Health: Risks and Responses. 2003.

This publication is a summary of the book Climate Change and Human Health – risks and Responses. Included in a paragraph on factors affecting vulnerability (pg. 11) to potential impacts of climate change (in general, not flooding specific) are population density, level of economic development, food availability, income level and distribution, local environmental conditions, pre-existing health status, and the quality and availability of public health care. In

some case, natural disaster impacts are increasing because of increasing vulnerability rather than increasing extreme climate events. Makes note of the need for assessment of population vulnerabilities and the identification of adaptive strategies.

Zhai G, Fukuzono T, Ikeda S. An empirical model of fatalities and injuries due to floods in Japan. *J Am Water Resour Assoc* 2006; 42:863-875.

This statistical modeling paper derives functions for predicting flood fatalities and injuries. The authors use physical damage to buildings and property as an "integrated index" that captures the relationships between flood intensity, regional vulnerability, and resilience. The idea is that by showing a relationship between damage and injuries or deaths, then damage data can be used to estimate the number of injuries and deaths in future scenarios. "Branch points" are determined, which indicate the likelihood of injury or death based on a certain number of damaged buildings in a flood. The authors consider different historical time periods and seasons to determine predictive functions (branch points) for certain scenarios. Interesting methods in this paper, but the authors do not include socio-demographic vulnerability data. Also, the utility of what these particular models tell us may not be all that helpful in terms of SEHIC indicator goals.