A Critical Analysis of Environmental Risk and Vulnerability in Flood Basins of the Houston-Galveston Area

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CRP: 386 Introduction to Geographic Information Systems
Executive summary
This study examines the different factors involved in assessing risks from hurricane events, flooding, and subsidence with risks from petrochemical and hazardous site contamination sparked by flood exposure. I utilized a modified version of the NOAA vulnerability assessment tool in order to assist in identifying populations at higher combined primary and secondary risk during a hazardous environmental event. I performed an analysis of combined primary environmental risk utilizing data from FEMA, NOAA, and the Texas Mitigation Package, as well as an analysis of combined secondary risk from hazardous sites utilizing data from Houston-Galveston Area Council, Texas General Land Office. Finally I utilized data from Houston-Galveston Area Council and the 2000 Federal Census to select demographic characteristics for Black, Hispanic, and Indigenous populations living in the region. I found that combined risk remains large along coastal areas of Harris and Galveston counties where Hispanic populations live in large concentrations of hazardous sites. However, combined risk for Black and Indigenous populations was considerably lower due to their locations relative to flood plains and hazardous sites. This was corroborated by overlaying my analysis with Google Earth satellite imagery to provide visual references of residential versus industrial areas. However, additional data are necessary to complete an integral analysis of combined risk for these populations; these data include structural housing quality, location of impervious surfaces, and protection and containment procedures of hazardous sites.

Introduction
After the critical damage caused by Hurricanes Katrina and Rita in 2005 in urban areas on the Louisiana coast, political, media, and activist attention has focused on the disproportionate impacts that primary environmental events such as hurricanes and hurricane-related flooding have on Black, Hispanic, and Indigenous populations living on the coast of the Gulf of Mexico. Much criticism was leveraged against the inefficiency with which the Bush administration and FEMA officials within that administration handled the exposure of these populations to environmental risk, including criticisms regarding inefficient warning systems, weak levee strength, and environmental racism during risk abatement planning and the factors behind the location of these populations in higher-risk urban neighborhoods. The possibility that this particularly toxic mix of environmental racism, environmental risk, and inefficient governmental response will only be isolated to the cases of Katrina and Rita in 2005 is very low; many areas of the Gulf Coast, and especially coastal areas of Texas and Louisiana, consist of Black, Hispanic, and Indigenous populations who, I hypothesize, face greater environmental risk, and therefore the possibility that these populations will face future impacts from hurricanes and hurricane-related flooding remains pervasive. As such, this project sought to assess the primary and secondary environmental risk and vulnerability of Black, Latino, and Indigenous populations in flood basins of another large urban metropolitan region: the seven-county Houston-Galveston area. This study utilized GIS to analyze the combined risk of primary and secondary environmental hazards for these populations, and aims to identify census tract areas of highest risk to support current preventative measures and future mitigation efforts of both environmental justice activists and FEMA operations.

The Houston-Galveston area was chosen among all possible sites along the Gulf Coast for a few reasons: first, it is the largest metropolitan area in terms of population; the larger 13 county area beyond the most populous 7 counties consists of 12,500 square miles and contains more than 5.7
million people (HGAC). Second, it is historically a racially segregated urban area as my demographic maps show. Third, Texas contains the largest amount and highest spatial concentration of petrochemical-related industry activity in the continental United States, and so presents a constant risk of industrial contamination. Finally, preliminary field visits to the Pasadena area in February 2008 with the support of environmental justice group Texas Environmental Justice Advocacy Services (T.E.J.A.S.) provided for preliminary observation of disproportionate exposure to benzine contamination of elderly Hispanic women living within “refinery row.”

Critically assessing the combination of risk and vulnerability of populations in the Houston-Galveston area is important for policymakers and for vulnerable neighborhoods alike, since disaster relief efforts are more likely to take into account energy interests rather than household interests. Producing data on households that are least capable of adapting to environmental risk would assist in preventative planning and in questioning the location of both energy infrastructure and vulnerable households in areas of environmental risk.

**Problem Statement**
In order to assess the combined primary and secondary environmental risk for Black, Hispanic, and Indigenous populations of the Houston-Galveston area, I posed the following questions:

1) Where is flood and erosion risk the greatest?

2) Where is risk from petrochemical and other hazardous material sites the greatest?

3) What households are most vulnerable to total flood, erosion, and hazardous materials risks?

4) What areas should be prioritized for preventative mitigation?

I hypothesized that a large percentage of these populations and not white populations lived near industrial sites such as petroleum and natural gas refineries are the most vulnerable to environmental risk. Although environmental racism does not only consist of racial factors but also economic inequality, immigrant status, age, multifamily housing, size of household, and other demographic data, I chose analyze race firstly. Other demographic categories that might go into a calculation of environmental racism and ultimately into analyses of total environmental risk may be included in future studies.

A subsequent issue with using racial population data is that, since individuals of all races may live in each county tract, a subjective criterion for highest population concentration relative to census tracts had to be made. Thus, I chose population concentrations of at least a third for each racial category given each census tract. Therefore, this study analyzes combined environmental risk for high concentrations of Black, Hispanic, and Indigenous populations across the study area.

**Literature Review**
Foucault (1979) argued that economic liberalism produces a “danger society” in which the transition from mercantilism and the interventionist state a state founded upon market logic
produces a constant sense of danger, or risk. Within this type of society individuals are expected as rationally behaving economic actors to calculate and potentially mitigate their own risk; it is no longer the responsibility, nor the interest, of state government to calculate, prevent, or mitigate the risk each individual faces. Rather, the state’s role within economic liberalism, Foucault argues, is transformed into one of promoting freedom of economic behavior, human capital, and competition as naturally occurring behaviors of all human beings. Rather than calculating and mitigating individual risks, the responsibility of government, he argues, transforms into calculating and mitigating the risks of populations insofar as they represent economic interests. I argue that government ineptitude and inefficiency vis-à-vis environmental risk management reflects this general trend towards economic liberalism as a foundational logic of the state. As such, populations with less economic opportunity both face higher risk, and bear the disproportionate costs of having to calculate and mitigate these risks themselves.

Similarly, Beck (1992) argued that modernity itself produces heightened risks in that the real dangers of technological hazards from industrial society “increasingly tend to escape the institutions for monitoring and protection” (5). Beck points to the globalization of industrial production, the flexibilization of labor, and the re-spatialization of information-based management and governmental regulation as culprits of this decoupling of risk from governmental institutions. This argument reflects Scott’s (1998) argument that state-managed development projects (including conservation and hazard mitigation) are bound to fail if they are removed spatially and socially from the detailed, local knowledge or what he calls “metis,” the everyday knowledge of how social relations and the environment interact. As such, the possibility that environmental risk management may actually aid at-risk populations, or even be formulated, organized, and practiced by themselves, will depend on the decentralization of risk management, knowledge, technologies, and techniques. Participatory GIS represents such a systematization of knowledge and technology that may be effective when incorporated at the local level (Elwood 2002).

Political ecology has also argued that people experience the environment and in this natural hazards in certain ways according to their relations to the political economy of the area in which they live. Blaikie’s (1995) chain of explanation illustrates how the experience, affect, and understanding of natural and secondary hazards depend on political economic decisions at various levels of political actors. Implicated in assessing primary and secondary environmental risk for non-white populations along the Gulf coast, then, must take into account not only governmental prevention, mitigation, and education plans, but also the specific political economy and power relations of political assemblages with petrochemical industries and lobbies. While entirely fundamental to assessing vulnerability of non-white populations living in flood areas and hazardous site zones, this study is outside of the realm of the following GIS analysis. However, it is significant to note that the potential of participatory GIS as a methodology for improved calculation, education, mitigation, and ultimately prevention of at-risk populations must necessarily take into account a political analysis of the economic factors that have predisposed governmental action towards protection of industrial and financial structures rather than of the populations that face higher risks and costs.
Methodology
I adopted the National Oceanic and Atmospheric Administration’s (NOAA) framework for environmental risk and vulnerability assessment. The purpose of such an assessment according to the NOAA is “to identify environmental resources that may be impacted by secondary hazards and target both the secondary hazard sites and the environmental resources for hazard mitigation activities.” This type of analysis is important to the Houston-Galveston area due to the confluence of high flood risk and high potential risk of contamination from petrochemicals and other hazardous material. Water is often a frequent vector for the spread of hazardous contaminants, and primary environmental hazards such as floods may “trigger” secondary hazards from storage facilities of contaminants, creating risk for “habitats, neighborhoods, and business” (NOAA). In order to assess the levels of risk the NOAA created the following schema:

*Step 1) Identify Secondary Risk Sites (Hazardous Facilities)

*Step 2) Identify where secondary risk sites (hazardous facilities) and natural hazard areas intersect. Overlay hazardous facilities with natural hazard areas to determine which of these facilities may cause secondary hazards

*Step 3) Prioritize the secondary risk sites (high-risk hazardous facilities) based upon their proximity to environmental resources. Overlay the hazardous facilities with environmental resource sites to determine their proximity to high-risk hazard areas. Prioritize these locations by listing which facilities are closest to environmental resources and might pose a threat in the event of a natural hazard.

*Step 4) Conduct a vulnerability analysis on prioritized secondary risk sites (hazardous facilities) and environmental resource sites

I modified the NOAA framework for the purposes of this project in order to assess not vulnerability of hazardous material structures, which is in itself an important factor in assessing total risk, but vulnerability of households to flood, hurricane, and subsidence risk and hazardous materials contamination. I normatively chose to analyze risk and vulnerability for Black, Hispanic, and Indigenous households as these populations have tended towards higher risk in previous flooding events along the Gulf coast.

Findings
The following maps are categorized in the following way:

1) A series of maps showing year 2000 population number per census tract for White, Black, Hispanic, and Indigenous/Multirace.
2) A series of maps showing preliminary findings of primary environmental risk, utilizing hurricane risk, flood risk, and subsidence risk.
3) A series of maps showing total hazardous sites within the immediate study area and a few selected areas of high hazardous concentration.
4) One map showing the final weighted environmental risk after calculating primary and secondary factors together.
5) A series of maps showing where high concentrations of population per race overlap with total risk values of 7 to 10.
In sum, the findings suggest that the Houston-Galveston area does not meet the overwhelmingly convincing criteria of disproportionately-borne environmental risk as evidenced in Louisiana during hurricanes Katrina and Rita. Nor do the findings suggest that environmental risk is greatest for these populations in the Galveston area, despite some claims after the landfall of Hurricane Ike. The findings do suggest, however, that total environmental risk is the greatest in areas where large hazardous concentrations meet large flood, hurricane, and subsidence risks. These areas include the areas immediately north and south of Houston city center where large Black populations are found; the area inwards along both sides of the ship channel including Pasadena, and also south of Lake Jackson, two areas where large Hispanic populations are found; between Pasadena and Houston city center, between Alvin and lower Galveston Bay, and West Houston by the reservoir, where large indigenous and multirace populations are found; perhaps the largest total risk near Channelview and Baytown where large white populations are found; and finally, near Texas City, large concentrations of hazardous sites overlap with primary environmental risk, but the haz sites themselves face larger immediate risks than do the populations living on the north side of the inlet.
White Population per Census Tract 2000

Datum: NAD 83
Projection: State Plane Texas South Central 4204 feet
Scale: 1:750,000

Houston-Galveston Area contains 7 counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

White Population

0 - 1575
1576 - 3251
3252 - 5050
5051 - 7819
7820 - 14058

Source: County Layers and Demographics: ESRI Tiger 2000
County Tracts, Major Thoroughfares, Roads, Reservoirs, Open Water, Rivers: Houston-Galveston Area Council

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Houston-Galveston Area contains 7 counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

Source: County Layers and Demographics: ESRI Tiger 2000
County Tracts, Major Thoroughfares, Roads, Reservoirs, Open Water, Rivers: Houston-Galveston Area Council
Hispanic Population per Census Tract 2000

Houston-Galveston Area contains 7 counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

Hispanic Population

- 0 - 915
- 916 - 2046
- 2047 - 3628
- 3629 - 5846
- 5847 - 11596

Source: County Layers and Demographics: ESRI Tiger 2000
County Tracts, Major Thoroughfares, Roads, Reservoirs, Open Water, Rivers: Houston-Galveston Area Council
Datum: NAD 83
Projection: State Plane Texas South Central 4204 feet
Scale: 1:750,000
Miles

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Indigenous & Multirace Population per Census Tract 2000

Houston-Galveston Area contains 7 counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

Source: County Layers and Demographics: ESRI Tiger 2000
County Tracts, Major Thoroughfares, Roads, Reservoirs, Open Water, Rivers: Houston-Galveston Area Council

Scale: 1:750,000
Datum: NAD 83
Projection: State Plane Texas South Central 4204 feet
Preliminary Flood Risk Analysis

Houston-Galveston Area contains 7 counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.


Datum: NAD 83
Projection: State Plane Texas South Central 4204 feet
Scale: 1:750,000

A = 1% percent or greater annual chance of flooding
AE = 1% percent or greater annual chance of flooding with elevation
AH = 1% percent or greater annual chance of shallow ponding
AO = 1% percent or greater annual chance of shallow sheet flow
VE = 1% percent or greater annual chance of flooding and velocity wave hazards
Preliminary Hurricane Risk Analysis

Zones correlate with hurricane strength categories 1-5 (see Saffir-Simpson scale for Hurricane Tracks above) and the wind/surge damage associated. Risk zones of higher hurricane strength categories also include the zones of lower hurricane strength. For example, locations within zones at risk from a category 3 hurricane also include the 1 and 2 categories/zones.

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Preliminary Subsidence Risk Analysis

Datum: NAD 83
Projection: State Plane Texas South Central 4204 feet
Scale: 1:750,000

Subsidence Risk Zones
- Less than 2.4
- 2.4 - 4.3
- 4.3 - 6.2
- 6.2 - 8.1
- 8.1 - 10

Hazardous Sites
- Cities
- Major Thoroughfare
- Roads
- Reservoirs
- Rivers

Houston-Galveston Area contains 7 counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

Source: FEMA Subsidence Risk Zones, Haz Sites: Texas Hazard Mitigation Package; County Layers and Roads: ESRI Tiger 2000; Cities, Major Thoroughfares, Reservoirs, Open Water, Rivers: Houston-Galveston Area Council

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Preliminary Hazardous Site Analysis

Datum: NAD 83
Projection: State Plane Texas South Central 4204 feet

Houston-Galveston Area contains 7 counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

Hazardous Waste Sites: 2004
Radioactive Waste Sites: 2000
Superfund Sites: 2004
Petrochemical Plants

Source: Haz Sites: Texas Hazard Mitigation Package; County Layers and Roads: ESRI Tiger 2000; Cities, Major Thoroughfares, Reservoirs, Open Water, Rivers, Pipelines, Ship Channel: Houston-Galveston Area Council

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Houston-Galveston Area contains 7 counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

Cities
Hazardous Waste Sites: 2004
Radioactive Waste Sites: 2000
Superfund Sites: 2004
Petrochemical Plants
Petrochemical Refineries
Ship Channel
Pipelines
Reservoirs/Reservoirs
County Borders

Source: Haz Sites: Texas Hazard Mitigation Package; County Layers and Roads: ESRI Tiger 2000; Cities, Major Thoroughfares, Reservoirs, Open Water, Rivers, Pipelines, Ship Channel: Houston-Galveston Area Council

Preliminary Hazardous Site Analysis Pasadena
Datum: NAD 83
Projection: State Plane Texas South Central 4204 feet
Scale: 1:159,365

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Houston-Galveston Area contains 7 counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

Source: Haz Sites: Texas Hazard Mitigation Package; County Layers and Roads: ESRI Tiger 2000; Cities, Major Thoroughfares, Reservoirs, Open Water, Rivers, Pipelines, Ship Channel: Houston-Galveston Area Council
Houston-Galveston Area contains 7 counties:
Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

Hazardous Waste Sites: 2004
Radioactive Waste Sites: 2000
Superfund Sites: 2004
Petrochemical Plants

Source: Haz Sites: Texas Hazard Mitigation Package; County Layers and Roads: ESRI Tiger 2000; Cities, Major Thoroughfares, Reservoirs, Open Water, Rivers, Pipelines, Ship Channel: Houston-Galveston Area Council
La Porte

Datum: NAD 83
Projection: State Plane Texas South Central 4204 feet

Houston-Galveston Area contains 7 counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

Source: Haz Sites: Texas Hazard Mitigation Package; County Layers and Roads: ESRI Tiger 2000; Cities, Major Thoroughfares, Reservoirs, Open Water, Rivers, Pipelines, Ship Channel: Houston-Galveston Area Council

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Combined Primary and Secondary Environmental Risk

Datum: NAD 83
Projection: State Plane Texas South Central 4204 feet

Houston-Galveston Area contains 7 counties:
Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

Source: Haz Sites: Texas Hazard Mitigation Package; County Layers and Roads: ESRI Tiger 2000; Cities, Major Thoroughfares, Reservoirs, Open Water, Rivers: Houston-Galveston Area Council

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Black Population and Environmental Risk

Houston-Galveston Area contains 7 counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

Source: County Layers and Demographics: ESRI Tiger 2000; County Tracts, Major Thoroughfares, Roads, Reservoirs, Open Water, Rivers: Houston-Galveston Area Council

Datum: NAD 83
Projection: State Plane Texas South Central 4204 feet
Scale: 1:644,081

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Houston-Galveston Area contains 7 counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.
Hispanic Environmental Risk

Houston-Galveston Area contains 7 counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

Source: County Layers and Demographics: ESRI Tiger 2000; County Tracts, Major Thoroughfares, Roads, Reservoirs, Open Water, Rivers: Houston-Galveston Area Council
Hispanic Environmental Risk in Pasadena

Houston-Galveston Area contains 7 counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

Datum: NAD 83
Projection: State Plane Texas South Central 4204 feet
Scale: 1:176,167

Hispanic > 3000
Risk Level
7
8
9
10
Hazardous Sites
Cities
Major Thoroughfare
Roads
Reservoirs
Rivers

Haz sites: Texas Hazard Mitigation Package; County Layers: ESRI Tiger 2000; HGAC Region, Planned Reservoirs, Reservoirs, Open Water, Streams: Houston-Galveston Area Council

Zachary Hurwitz
December 15, 2008
Hispanic Environmental Risk in Lake Jackson

Datum: NAD 83
Projection: State Plane Texas South Central 4204 feet

Houston-Galveston Area contains 7 counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

Hispanic > 3000

Risk Level

Haz sites: Texas Hazard Mitigation Package; County Layers: ESRI Tiger 2000; HGAC Region, Planned Reservoirs, Reservoirs, Open Water, Streams: Houston-Galveston Area Council

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Indigenous and Multirace Environmental Risk

Houston-Galveston Area contains 7 counties:
Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

Scale: 1:600,000
Datum: NAD 83
Projection: State Plane Texas South Central 4204 feet

Source: County Layers and Demographics: ESRI Tiger 2000; County Tracts, Major Thoroughfares, Roads, Reservoirs, Open Water, Rivers: Houston-Galveston Area Council

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Indigenous and Multirace Risk East Houston

Houston-Galveston Area contains 7 counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

Datum: NAD 83
Projection: State Plane Texas South Central 4204 feet
Scale: 1:198,668

Haz sites: Texas Hazard Mitigation Package; County Layers: ESRI Tiger 2000; HGAC Region, Planned Reservoirs, Reservoirs, Open Water, Streams: Houston-Galveston Area Council

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December 15, 2008
Indigenous and Multirace Risk West Houston

Datum: NAD 83
Projection: State Plane Texas South Central 4204 feet

Houston-Galveston Area contains 7 counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

Haz sites: Texas Hazard Mitigation Package; County Layers: ESRI Tiger 2000; HGAC Region, Planned Reservoirs, Reservoirs, Open Water, Streams: Houston-Galveston Area Council

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White Environmental Risk

Houston-Galveston Area contains 7 counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

Source: County Layers and Demographics: ESRI Tiger 2000; County Tracts, Major Thoroughfares, Roads, Reservoirs, Open Water, Rivers: Houston-Galveston Area Council

Datum: NAD 83
Projection: State Plane Texas South Central 4204 feet
Scale: 1:750,000

White > 3000 Risk Level

Cities
Census Tracts
Major Thoroughfare
Roads
Reservoirs
Rivers

Miles

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Houston-Galveston Area contains 7 counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

Population > 3000

Risk Level
- 7
- 8
- 9
- 10

# Hazardous Sites

Cities

Major Thoroughfare

Roads

Reservoirs

Rivers

Source: Haz sites: Texas Hazard Mitigation Package; County Tracts and Demographics: ESRI Tiger 2000

Major Thoroughfares, Reservoirs, Open Water, Roads, Rivers: Houston-Galveston Area Council

Datum: NAD 83
Projection: State Plane Texas South Central 4204 feet
Scale: 1:177,030

White Environmental Risk Baytown

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White Environmental Risk Texas City and Galveston

Houston-Galveston Area contains 7 counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

Risk Level

1. Population > 3000

2. Hazardous Sites

3. Cities

4. Major Thoroughfare

5. Reservoirs

6. Roads

7. Rivers

Source: Haz sites: Texas Hazard Mitigation Package; County Tracts and Demographics: ESRI Tiger 2000
Major Thoroughfares, Reservoirs, Open Water, Roads, Rivers: Houston-Galveston Area Council

Datum: NAD 83
Projection: State Plane Texas South Central 4204 feet

Scale: 1:283,425

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December 15, 2008
Environmental Risk in Galveston

Houston-Galveston Area contains 7 counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

Source: Risk Levels: Original Analysis; FEMA Post-Ike Google Earth Imagery: National Oceanic and Atmospheric Agency (NOAA)
Environmental Risk in Texas City

Houston-Galveston Area contains 7 counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

Source: Risk Levels: Original Analysis; FEMA Post-Ike Google Earth Imagery: National Oceanic and Atmospheric Agency (NOAA)

Datum: NAD 83
Projection: State Plane Texas South Central 4204 feet
Scale: 1:96,973

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December 15, 2008
Environmental Risk in Pasadena

Houston-Galveston Area contains 7 counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

Source: Risk Levels: Original Analysis; FEMA Post-Ike Google Earth Imagery: National Oceanic and Atmospheric Agency (NOAA)

Datum: NAD 83
Projection: State Plane Texas South Central 4204 feet

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December 15, 2008
Houston-Galveston Area Elevation in Feet

Datum: NAD 83
Projection: State Plane Texas South Central 4204 feet

Houston-Galveston Area contains 7 counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Montgomery.

Source: Elevation with Hillshade: National Elevation Data; Reference Elevation: Texas Hazard Mitigation Package; Reservoirs, Open Water, Rivers, Cities: Houston-Galveston Area Council; Urban Outlines: Texas General Land Office

Scale: 1:750,000  December 15, 2008

Mean Sea Level-50 Feet
50-250 Feet
250-500 Feet
500-1000 Feet
1000-2000 Feet
2000-3000 Feet
3000-4000 Feet
4000-5000 Feet
5000-6000 Feet
Above 6000 Feet above msl

High : 174 feet
Low : Sea Level

Cities
Reservoirs
Urban Areas

Elevation with Hillshade
Conclusions
Calculating primary environmental risk for the Houston-Galveston area, and where this risk combines with secondary environmental risk produced by exposure to vector-based contamination from hazardous sites should normatively account for populations who have faced disproportionate impacts from both risks along the Gulf coast. However, calculating both primary and secondary risks and their combined risk would benefit from additional data. First, flood risk maps by FEMA are only available insofar as they make reference to flood insurance, or rather, where there is at least a 1% risk of 100-year flooding associated with specific types of flooding. The maps are made available only insofar as they illustrate areas where flood insurance is considered mandatory and non-mandatory by the Department of Homeland Security. As such, real flood risk as defined by flooding due to a hurricane event has not been calculated. Second, hurricane events and the risk derived from their occurrence depends both on seasonality and ocean temperature during any given hurricane season; hurricane tracks depend on combinations of atmospheric and oceanic factors. As such, static hurricane risk calculations should take into account solely vulnerability factors including structural integrity. Third, both exposure to risk from both factors depends significantly on percentage of land covered by impervious surfaces, drainage areas, and construction of runoff channels. Fourth, current data do not take into account structural integrity of flood walls and levees. Fifth, the degree to which flood water acts as a vector for hazardous contamination depends largely on the structural integrity and containment procedures of hazardous sites, and if runoff from these sites happens to coincide with flood basin directionality. Finally, vulnerability data could be refined in these maps utilizing SF3 data to account for immigrant status, age, and other factors that would make risk levels increase. Such a GIS production would benefit from being placed in the hands of local communities and community activists who have easier access to these kinds of data about vulnerable populations.

Finally, it is important for a critical risk analysis of primary and secondary environmental risk for this area to take into account the political economic factors that dispose these populations to bear unwarranted risks from both flooding and hazardous contamination. What prompts the government to require that the individual purchase flood risk insurance rather than providing preventative assistance to relocate these populations away from areas of highest risk?

Rather than displace the responsibility for mitigating environmental risk to the economic capabilities of highest-risk individuals, FEMA, the Texas government, and the federal government could consider an overall restructuring of Gulf coast risk prevention, mitigation, and abatement. The built environment along the Gulf coast includes a toxic mix of racially segregated populations; high primary environmental risk from flooding, hurricanes, subsidence, and erosion; and the largest concentration of petrochemical and other hazardous sites in the country. Given the seasonality and the reoccurrence of primary environmental events, and given the economic and national security significance of the petrochemical matrix in this area, three recommendations should be considered:

1) Relocate and compensate the most vulnerable families and populations from areas of highest risk to areas of lowest risk;
2) Mandate the closure of the oldest and most hazardous structures and sites along the areas of primary environmental risk;
3) Create conservation areas including constructed wetlands environments of mangrove plantations, which naturally prevent soil erosion and assuage dangerous wind and storm surge events;

The combination of a highly dangerous built environment with a highly dangerous physical environment along the Houston-Galveston area and in the Gulf coast in general should be seriously considered by FEMA, the Department for Homeland Security, and development planners. The current economic matrix that has formed around the production and refinery of oil and the utilization of certain shoreline and hydrological aspects of Galveston Bay for the operation of this matrix currently decreases the possibility that populations or neighborhoods located in areas of high total risk to these factors might be relocated and compensated. If the government is to avoid another toxic combination of hurricanes, flooding, and petrochemical contamination, and erase the pervading perception that economically disadvantaged populations are disposable and have been left to face the costs of environmental risk on their own, action must be taken quickly.

**Data sources**

- Google Earth imagery

**References**

Appendix:
List of data utilized for each map set:

Map set A) Primary environmental risk:
  THMP State Flood risk zones FEMA
  THMP Hurricane risk zones
  THMP Subsidence risk zones
  HGAC Coastal Openwater
  HGAC Planned reservoirs
  HGAC Reservoirs
  HGAC Streams
  HGAC Watershed
  HGAC River basins
  HGAC Subbasins
  THMP Texas Elevation
  NED Texas Elevation
  TIGER Brazoria Cty tracts
  TIGER Chambers Cty tracts
  TIGER Fort Bend Cty tracts
  TIGER Galveston Cty tracts
  TIGER Harris Cty tracts
  TIGER Montgomery Cty tracts
  TIGER Liberty Cty tracts

Suggested additional data: Storm surge data layer.

Action log:
Projected all data into NAD 83 State Plane Texas South Central 4204 feet.
Added FEMA flood risk polygon. Edited attribute table to reclassify all A1-30 and V1-30 as AE
and VE respectively. Reduced flood zones to 5 categories and symbolized choosing VE as most
dangerous due to storm surge risk.
Added rivers, openwater, reservoirs, watershed, basins, subbasins layers for initial reference.
Deleted basins, subbasins.
Added THMP hurricane risk polygon. These were already categorized as 1-5 risk zones
according to potential for damage from hurricane strength, each zone including risks of the lower
risk zones.
Added THMP subsidence risk zones. This came in polyline format and so had to be converted
into polygon using feature to polygon function in order to calculate it together with the other risk
factors. To do this I edited the subsidence risk polygon attribute table to add a new ‘double’
field called 'value.' I manually added in the values by selecting each row to double check its
value against the original layer.
Added 7 county tract layers and merged into HGAC county layer.
Clipped all previous layers to HGAC county layer.
Added THMP elevation feature and NED elevation rasters in separate map. NED rasters came in
grids that needed to be mosaicked. I mosaicked 5 NED rasters to combine elevation data.
NOAA elevation rasters, although more precise, were too numerous and too heavy to mosaic given the timeframe.

Map set B) Secondary environmental risk (hazardous sites analysis):
- HGAC Shipchannel
- HGAC Pipelines
- HGAC Petrochemical plants
- HGAC Refineries
- THMP Hazardous Cargo Routes
- THMP Hazardous Waste Sites 2004
- THMP Radioactive Waste Sites 2000
- THMP Superfund Sites 2000
- THMP Texas Elevation
- TIGER Brazoria Cty tracts
- TIGER Chambers Cty tracts
- TIGER Fort Bend Cty tracts
- TIGER Galveston Cty tracts
- TIGER Harris Cty tracts
- TIGER Montgomery Cty tracts
- TIGER Liberty Cty tracts

Suggested additional haz data: gas stations and other less reinforced haz sites.

Action log:
- Projected all data into NAD 83 State Plane Texas South Central 4204 feet.
- Added all hazardous sites (points) into separate map. Symbolized to differentiate hazardous type. Merged haz sites into “mergedhaz” layer. Dissolved unnecessary categories from att table of mergedhaz layer.
- clipped mergedhaz layer to the merged HGAC county layer.
- Initial analysis (crude): Placed 1-mile buffer around merged haz sites. Decided this would not be sufficient and that spatial analysis had to be performed on merged haz sites to calculate total risk.

Map set C) Analysis of combined primary and secondary environmental risk:
Combining previous data layers into one analysis.

Actions log:
- Rasterized all polygons that were not rasterized- flood, hurricane, subsidence- using 100 cell extent through feature to raster tool.
- Rasterized mergedhaz layer using 200 cell extent distance analysis in spatial analyst.
- Reclassified mergedhaz layer into 10 equal breaks.
- Rasterized subsidence layer was reclassified from 1-9 to 2-10 to reflect 10 as highest rank (most risk/danger).
- Rasterized flood layer and rasterized hurricane layer came out expressed from 1-5. Therefore I had to calculate each one separately by multiplying each by 2 using raster calculator. That reclassified each layer into weights of 10, still classified in 5 categories, but with scores of 0, 2, 4, 6, 8, 10.
Reclassified to make sure that “No Data” was given a value of 0, since the extents did not match and since each raster did not take up the whole space of the HGAC boundaries until I gave “No Data” a 0 score.

Calculated total risk of four rasters: hurricane risk, flood risk, subsidence risk, and mergedhaz risk. I calculated two versions of risk: equal weights (25% each layer) and tapering risk (40% flood, 30% hurricane, 20% haz sites, and 10% subsidence). Each told a different story. The tapered risk showed heavy risk along all immediate coastal regions. Equal risk showed more balanced risk throughout the region.

Then realized I had yet to flip hurricane risk zones (erroneously I reclassified coastal areas as highest risk, when risk level 5 of hurricane layer is well inland!). So reclassified and recalculated once more. I kept the equal weighted risk as showing a more dynamic story.

Converted final weight into feature and symbolized as reference.

Map set D) Total Risk and Demographics

- TIGERBrazoria Cty tracts
- TIGERChambers Cty tracts
- TIGERFort Bend Cty tracts
- TIGERGalveston Cty tracts
- TIGERHarris Cty tracts
- TIGERMontgomery Cty tracts
- TIGER Liberty Cty tracts
- TIGERSF1 Texas state demographics

Feature class total risk weight

Action log:
Downloaded SF1 for statewide county tracts
Joined SF1 table to merged HGAC county layer
Symbolized different maps according to racial demographics.
Selected by attribute specific county tracts where population > 3000 for white, black, and Hispanic. Population was maximum 130 per Indigenous per census tract, so combined it with multirace per census tract and selected by attribute population > 100 indigenous and population > 300 multirace. Subjective choice.
Created separate layers and exported these layers into permanent shapefiles called population > (and then the respective race and number of population).
Decided not to perform intersect between total risk calculation and each demographic selection since intersect areas would have been very small. Decided instead to overlay the two sets of data on top of each other so we could see both strong concentrations of given racial category and a few neighborhoods where total risk was in the top 30% (score 7-10).
Imported total risk layer into separate map of zoomable Google Earth imagery downloaded from NOAA to reference built structures versus residential neighborhoods underneath undifferentiated demographics per census tract layers.

SUGGESTED ACTION: Geocode addresses to label neighborhoods most at risk.
More data is needed to address issues identified in report.