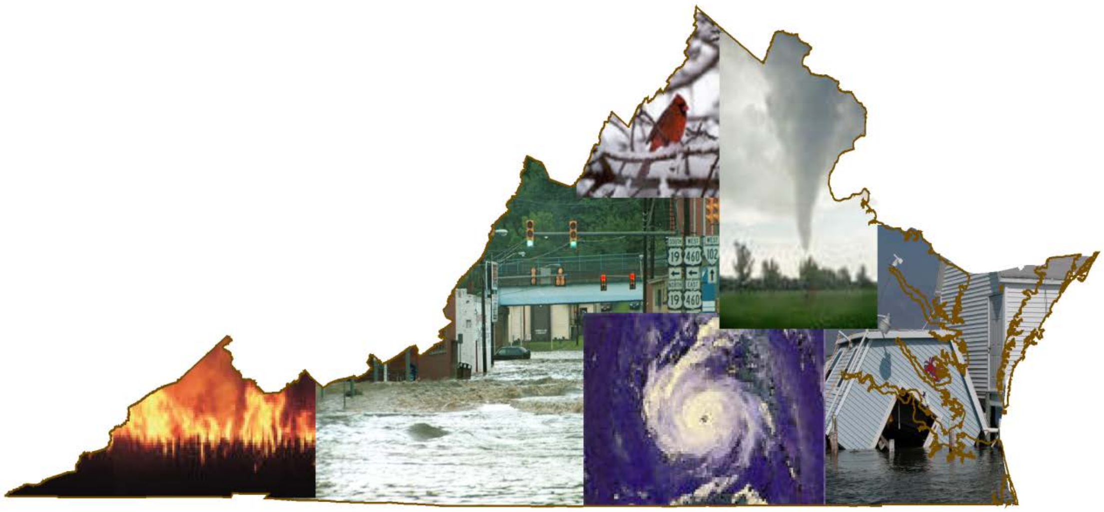
COMMONWEALTH OF VIRGINIA

Hazard Mitigation Plan



Chapter 3
Hazard Identification and Risk Assessment (HIRA)

Appendix 3.5 – Hazard Assessment and Ranking Methodology

SECTION 3.5

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Section 3.5: Hazard Assessment and Ranking Methodology

This chapter describes the concepts underlying the hazard identification and risk assessment process, and the methods used to rank hazard risk. These concepts underlie the individual hazard chapters that follow. The HIRA sub-committee reviewed the process used to identify the hazards during the May 10, 2012 Kickoff meeting.

Criteria for Hazards, Vulnerability, and Risk Assessment

The following risk assessment has been structured to identify:

1. Geographic Area Affected
2. Historical Occurrences
3. Probability of Future Events
4. Vulnerable Populations

For the purposes of compliance with the Disaster Mitigation Act as further specified by Interim Final Rule 44 CFR Section 206.401(c)(2)(i), this Plan addresses in full only the hazards in section 3.1 of this chapter. Additional hazards will be more fully addressed during future Plan updates as their respective significance warrants.

Terminology

The definition of terms can cause confusion in mitigation planning. This is evident in the review of 25 Local Mitigation Plans, in which definitions of key terms varied substantially. Section 3.6 of this chapter describes the local planning efforts and the hazards addressed by each planning area.

Maintaining clear terminology in the 2013 HMP revision process is an important priority. To improve consistency, the following discussion identifies working definitions and expanded meanings of key terms as found in references consulted during the exploration of this issue.

Probability

In this study, probability is the odds (or chance) of a certain event, of a certain magnitude, occurring in a given time period. In the strictest sense, probability must be expressed with a quantitative statement of chance. However, when the exact probability has not been studied, a qualitative statement of risk must suffice.

Two primary methods exist for determining the probability of a hazard's occurrence: statistical analysis of historical occurrences and models of probable occurrence.

Statistical analysis of historical occurrence can be applied to large databases. These databases may include the time, intensity, location, and damages caused by an event. Examples of such databases include weather conditions, wildfire occurrences, and sinkhole reports. Determining the historic frequency of occurrence of certain events may be sufficient to estimate future rates of occurrence, if the event occurs at a relatively steady rate. However, a major drawback to this method of probability estimation is that errors, biases, and incomplete reporting in the historical database can lead to inaccurate projections.

In contrast to pure statistical analysis, models of probable occurrence predict hazard probability based on a more theoretical basis. While many models are often calibrated to historical data, they have the capability to predict occurrences that would not be otherwise observed, due to the lack of witnesses for extremely rare events. Examples of such models include flood maps depicting 100 and 500-year floodplains (1% and 0.2% annual chance events), storm surge inundation models, karst susceptibility maps based on geologic conditions, fire risk, and many others.

The desired result of a probability analysis is the creation a dataset that communicates not only the probability of occurrence, but also the spatial extent and intensity. A statement of probability alone, without some associated intensity, is not always useful if the hazard in question occurs frequently, and with widely varied intensity.

Vulnerability& Impact

> *§201.4(c)(2)(ii) [The state plan shall have] An overview and analysis of the State's vulnerability to the hazards described in this paragraph (c)(2), based on estimates provided in local risk assessments as well as the State risk assessment. The State shall describe vulnerability in terms of the jurisdictions most threatened by the identified hazards, and most vulnerable to damage and loss associated with hazard events. State owned critical or operated facilities located in the identified hazard areas shall also be addressed.*

Vulnerability may be defined as the degree to which a certain receiving body may be damaged by a hazard event. Jurisdictional vulnerability is often directly related to the number and type of people in certain hazard-prone areas. Facility vulnerability, on the other hand, may be directly related to structural capacity, fire suppression systems, and other reinforcements against hazards.

Within jurisdictional vulnerability, special attention may be paid to social vulnerability. Certain members of a society are more vulnerable to disaster events for various reasons. Future revisions to this plan should include this as a factor of vulnerability. Several studies outline methods to consider socioeconomic status when calculating the overall vulnerability of a certain geographic location. One particularly promising analysis method creates a social vulnerability index using readily available U.S. Census data and has been used in several other hazard risk assessments.[1]

This report analyzes both jurisdictional and facility-specific vulnerability. Jurisdictional vulnerability includes population and other demographic factors, aggregated building values, and the net numbers of local critical facilities impacted by a potential hazard. Facility-specific vulnerability is the result of the physical properties of a facility: the construction type, standards, and age; elevation and number of stories; fire suppression; and various other factors. Ultimately, vulnerability is often summarized in the form of an intensity-damage relationship developed from an analysis of historical hazard impacts.

Impact may be defined as the actual effect of a hazard event on a certain receiving body. Jurisdictional impact could be quantified as the actual number of people affected by an event, or other measures of the effect of the hazard on the jurisdiction. Facility impact could be the financial losses that occur because of damage to the facility by a well-defined hazard event.

Impact is difficult to accurately predict from a purely theoretical perspective. Usually, historical data is analyzed in order to assess quantified damages, deaths, and injuries that result from specific events of specific intensities. This analysis may result in intensity-damage relationships which can be used to estimate the impact of specific hazard scenarios in the future.

[1] Susan L. Cutter, et al. Social Vulnerability to Environmental Hazards Social Science Quarterly, 2003

Risk

Risk is "the estimated impact…[and]…the likelihood of a hazard event…" Risk is often expressed in relative terms such as a high, moderate, or low likelihood of sustaining damage above a particular threshold. It also can be expressed in terms of potential monetary losses associated with the intensity of the hazard.[2]

The risk associated with a certain hazard can also be described as the probability of that hazard's occurrence multiplied by its impact. When probability is expressed as annual chance, risk may be calculated as annualized loss. For many hazards, different probabilities may be associated with varying intensities. In these cases, the combined risk due to a certain hazard is equal to the sum of the risk associated with each intensity level.

Ranking Methodology

To compare the risk of different hazards, and prioritize which are more significant, requires a system for equalizing the units of analysis. Under ideal conditions, this common unit of analysis would be "annualized dollars." However, such an analysis requires reliable probability and impact data for all the hazards to be compared. As this is often not the case, many hazard prioritization methods are based on scoring systems, which allow greater flexibility, and more room for expert judgment.

CGIT and VDEM have developed a standardized methodology to compare different hazards' risk on a jurisdictional basis. As some of the hazards assessed in this plan did not have precisely quantifiable probability or impact data, a semi-quantitative scoring system was used to compare all of the hazards. This method prioritizes hazard risk based on a blend of quantitative factors from the available data. A number of parameters have been considered in this methodology, all of which could be derived from the NCDC database (section 3.3):

- History of occurrence
- Vulnerability of people in the hazard area
- Probable geographic extent of the hazard area
- Historical damages, in terms of crop and property

[2] FEMA Publication 386-2: Mitigation Planning How-to-Guide: Understanding Your Risks

The ranking methodology tries to balance these factors, whose reliability varies from hazard to hazard due to the nature of the underlying data. Each parameter was rated on a scale of one (1) through four (4). The exact weights were highly debated, but the final conclusion was that the population vulnerability and density would each be weighted at 0.5 and geographic extent at 1.5, relative to the other parameters. These scores are summed at a jurisdictional level for each hazard separately, permitting comparison between jurisdictions for each hazard type. A summation of all the scores from all hazards in each jurisdiction provides an overall, "all-hazards" risk prioritization. The following sections provide an overview of the six parameters that were used in ranking the hazards that impact Virginia.

The NCDC data, as described in section 3.3, is far from a complete data source. This data was used for the ranking because of its standardized collection of many of the hazards of interest. The data only partially represents the geological hazards and as a result the ranking can only characterize the current form of the data. As other data sources become available the ranking will need to be reassessed to make sure the parameters are still valid for ranking the hazards.

Population Vulnerability and Density

Population vulnerability and density are simple, yet important factors in the risk ranking assigned to a jurisdiction. In general, a hazard event that occurs in a highly populated area has a much higher impact than a comparable event that occurs in a remote, unpopulated area. Two population parameters were used, accounting for jurisdictions with high populations and jurisdictions with densely populated areas. Each parameter was given a weighting of 0.5 in an effort to avoid overwhelming the overall ranking methodology with pure population data.

Population vulnerability was calculated as the percent of the total population of Virginia present in each jurisdiction. 2010 U.S. Census population for each jurisdiction were divided by the total population for the state; a value between one and four was assigned based on a geometric breaks pattern. By ranking jurisdictions this way, those cities and counties with significantly larger populations have effectively been given extra weight. Table 3.5-1 below describes the breaks and assigned scores for population vulnerability.

Table 3.5-1: Population Vulnerability as the percentage of people that will be affected by the occurrence of the hazard

Population Vulnerability	
Rank	Definition
1	<= 0.229 % of the total population of the state
2	0.230% - 0.749% of the total population of the state
3	0.750% - 2.099% of the total population of the state
4	> = 2.100% of the total population of the state

Population density was based on the population per square mile for each jurisdiction. 2010 population data for each jurisdiction was divided by the total area for the jurisdiction; a value between one and four was assigned based on geometric intervals. By ranking jurisdictions this way, those cities and counties with densely populated areas have effectively been given extra weight. Table 3.5-2 below describes the breaks and assigned scores for population density.

Table 3.5-2: Population Density as the number of people per square mile that will be affected by the occurrence of the hazard

Population Density	
Rank	Definition
1	<= 60.92 people/sq mi
2	60.93 – 339.10 people/sq mi
3	339.11 - 1,743.35 people/sq mi
4	>= 1,743.36 people/sq mi

Geographic Extent

Probable geographic extent (GE) would ideally be measured consistently for each hazard; however, the available data sources vary widely in their depiction of hazard geography. As a result, one uniform ranking system could not be accomplished at this time. In this version of the plan each hazard has been assigned individual category break points based on the available hazard data. In the overall scoring system, geographic extent was given a 1.5 weighting relative to the other parameters, as geographic extent was deemed to be critically important, and more reliable than some of the other parameters. GE data sources, ranking criteria, and category breaks are summarized in Table 3.5-3 below.

Table 3.5-3: Geographic Extent as the percentage of a jurisdiction impacted by the hazard

Geographic Extent			
Hazard	**Description**	**Category Breaks**	
		Rank	Definition
Flood	Percent of a jurisdiction that falls within FEMA Special Flood Hazard Area (SFHA).	1	<=2.99%
		2	3.00-4.99%
		3	5.00 -9.99%
	Data: FEMA Floodplains (DFIRMs)	4	>=10.00%
High Wind	Average maximum wind speed throughout the entire jurisdiction.	1	<= 59.9
		2	60.0 - 73.9
	Data: HAZUS 3-second Peak Gust Wind Speeds	3	74.0 - 94.9
		4	>= 95.0
Wildfire	Percent of jurisdiction that falls within a “high” risk.	1	<= 9.9%
		2	10.0% - 19.9%
		3	20.0% - 49.9%
	Data: VDOF Wildfire Risk Assessment	4	>= 50.0%
Karst	Percent of jurisdiction where the risk is “high” for karst related events.	1	<= 24.9%
		2	25.0% - 49.9%
		3	50.0% - 74.9%
	Data: USGS Engineering Aspects of Karst	4	>= 75.0%
Landslide	Percent of jurisdiction where a high landslide risk exists.	1	<= 24.9%
		2	25.0% - 49.9%
	Data: USGS Landslide Incidence & Susceptibility	3	50.0% - 74.9%
		4	>= 75.0%
Earthquake	Average 2500-year return period max percent of gravitational acceleration (PGA).	1	<= 0.069
		2	0.070 - 0.159
		3	0.160 - 0.299
	Data: HAZUS 2500-year PGA	4	>= 0.300
Winter Storm	Average annual number of days receiving at least 3 inches of snow, calculated as an area-weighted average for each jurisdiction.	1	<= 1.49
		2	1.50 - 1.99
		3	2.00 - 2.99
	Data: NWS snowfall statistics	4	>= 3.0
Tornado	Annual tornado hazard frequency (times one million), calculated as an area-weighted average for each jurisdiction.	1	<= 1.24
		2	1.25 - 9.99
		3	10.00 - 99.9
	Data: NCDC tornado frequency statistics	4	>= 100.00

Annualizing the Data for Analysis

Data from the NCDC database was annualized in order to be able to compare the results on a common system. In general, this was completed by taking the parameter of interest and dividing by the length of record for each hazard. The annualized value should only be utilized as an estimate of what can be expected in a given year. Property and crop damage were annualized in the fashion. A summary of the parameters and the period of record used for each hazard can be found in the Section 3.3 which further describes the NCDC data.

Annualized Deaths and Injuries

Deaths and Injuries are also an important factor to evaluate when determining risk ranking. Using NCDC data, past deaths and injuries were computed for drought, flood, high wind, tornado, wildfire, and winter storm. The remaining hazards have no reported deaths or injuries in this database and as a result were assigned a ranking of one (1).

In order to consolidate the data, fatalities were given a weight of 176 times that of an injury, and then added together. This follows the standard practice used for FEMA cost benefit analysis[3]. The combined injury/death values were annualized over the period of record for each event category and scored, using natural breaks (Table 3.5-4). A summary of deaths/injuries and the period of record used for each hazard can be found in the section 3.3 (Table 3.3-3) which describes the NCDC data.

Table 3.5- 1: Annualized Deaths and Injuries as the number of deaths or injuries that a hazard event would likely cause in a given year.

Annualized Deaths and Injuries	
Rank	Definition
1	<= 1.019 deaths and/or injuries per year
2	1.020 – 6.279 deaths and/or injuries per year
3	6.280 – 13.199 deaths and/or injuries per year
4	>= 13.200 deaths and/or injuries per year

[3] 2006 FEMA Mitigation BCA Toolkit. July 2006, Version 3.0

Annualized Crop and Property Damage

Crop damage and property damage were also analyzed separately in order to give each jurisdiction a score of one (1) to four (4). This data was obtained from the NCDC storm events database and annualized according to the period of record for each event category (Table 3.5-5).

The period of record in NCDC varies dramatically by hazard type. A summary of crop and property damages and the period of record used for each hazard can be found in the section 3.3 (Table 3.3-3) which describes the NCDC data.

Table 3.5-4: Annualized Crop and Property Damage as the estimated damages that a hazard event will likely cause in a given year

Annualized Crop and Property Damage		
Rank	Definition: Crop Damage	Definition: Property Damage
1	<= $25,711 per year	<= $ 136,129 per year
2	$25,712 – $100,270 per year	$136,130 - $432,555 per year
3	$100,271 - $291,384 per year	$432,556 - $1,111,067 per year
4	>= $291,385 per year	>= $1,111,068 per year

Annualized Events

While each hazard may not have a comprehensive database of past historical occurrences, the record of historical occurrences is still an important factor in determining where hazards are likely to occur in the future. Annualizing the NCDC storm events data yields a rough estimate of the number of times a jurisdiction might experience a similar hazard event in any given year. To do this, the total number of events in the NCDC database, for each specific hazard in each jurisdiction, was divided by the total years of record for that hazard to calculate an "annualized events" value. A summary of events and the period of record used for each hazard can be found in the section 3.3 (Table 3.3-3) which describes the NCDC data.
It should be noted that there were no significant events reported for land subsidence (karst), earthquake, and landslide in NCDC; as a result, the events for these hazards all received a rank of one (1). Table 3.5-6 describes the annual frequency breaks for events.

Table 3.5- 2: Annualized Events as the number of times that a hazard event would likely happen in a given year.

Annualized Events	
Rank	Definition
1	<= 0.09 events per year
2	0.10 – 0.99 events per year
3	1.00 – 4.99 events per year
4	>= 5.00 events per year

Overall Hazard Ranking

The scores from each of these categories were added together for each hazard to estimate the total jurisdictional risk due to that hazard. As discussed previously, the population parameters were each given a weighting of 0.5 (for a total of 1.0 for all population parameters), and Geographic Extent was given a weighting of 1.5 relative to the other factors. The total scores were broken into five categories to better illustrate the distribution of risk scores. Those jurisdictions with scores from 0 to 8.49 were determined to have a low risk in that hazard category, scores 8.50 through 9.99 were considered medium-low risk, between 10.0 and 11.49, medium risk, between 11.50 and 12.99 were considered medium-high risk; and jurisdictional hazard scores greater than 13.00 were given a high rating.

Comparison of the overall hazards ranking with the local plan rankings is available in section 3.6 in Table 3.6-2. Ranking results and statewide analyses are available in section 3.16 of this chapter. Section 3.16b, appendix to Overall Hazard Results, includes the ranking spreadsheet and the established values/rank for all of the parameters by jurisdiction.