CHAPTER 3:
RISK ASSESSMENT

Coastal Erosion

Drought

Flooding

Winter Storms

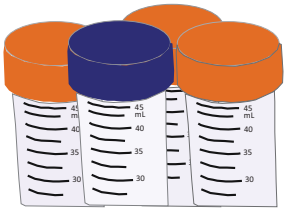
Coastal Storms

Earthquakes

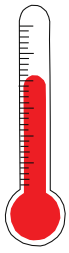
Severe Weather

Chemical, biological, radiological, and nuclear

Infrastructure Failures

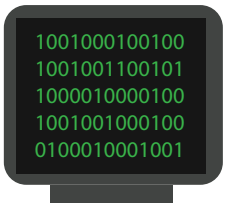


Disease Outbreaks



Extreme Temperatures

Wild Fires



Cyber Threats

1. INTRODUCTION 44

A. THE RISK ASSESSMENT PROCESS 44

B. FEMA AND NYS OEM REQUIREMENTS ADDRESSED IN THIS CHAPTER 44

2. HAZARD IDENTIFICATION 46

A. POTENTIAL HAZARDS 46

B. HAZARD SELECTION PROCESS 48

C. ELIMINATED HAZARDS 49

D. FINAL LIST OF NEW YORK CITY HAZARDS 49

3. HAZARD RISK ASSESSMENT ORGANIZATION 51

A. HAZARD PROFILE 51

B. VULNERABILITY ASSESSMENT 51

4. NEW YORK CITY'S HAZARD ENVIRONMENT 54

A. THE NATURAL ENVIRONMENT 54

B. THE SOCIAL ENVIRONMENT 59

C. THE BUILT ENVIRONMENT 71

D. THE FUTURE ENVIRONMENT 93

5. COASTAL EROSION 104

A. HAZARD PROFILE 104

B. VULNERABILITY ASSESSMENT 105

6. COASTAL STORMS 110

A. HAZARD PROFILE 110

B. VULNERABILITY ASSESSMENT 118

7. DISEASE OUTBREAKS 127

A. HAZARD PROFILE 127

B. VULNERABILITY ASSESSMENT 133

8. DROUGHT 137

A. HAZARD PROFILE 137

B. VULNERABILITY ASSESSMENT 140

9. EARTHQUAKES 144

A. HAZARD PROFILE 144

B. VULNERABILITY ASSESSMENT 151

10. EXTREME TEMPERATURES 157

A. HAZARD PROFILE 157

B. VULNERABILITY ASSESSMENT 164

11. FLOODING 171

A. HAZARD IDENTIFICATION 171

B. VULNERABILITY ASSESSMENT 186

12. HURRICANE SANDY RETROSPECTIVE ANALYSIS 200

A. SUMMARY 200

B. STORM CHARACTERISTICS 200

C. PRE-STORM PREPARATIONS IN NEW YORK CITY 201

D. IMPACTS ON NEW YORK CITY 202

E. POST-STORM RECOVERY 207

F. LESSONS LEARNED 209

13. SEVERE WEATHER: THUNDERSTORMS, TORNADOES, AND WINDSTORMS 211

A. HAZARD PROFILE 211

B. VULNERABILITY ASSESSMENT 221

14. WILD FIRES 224

A. HAZARD PROFILE 224

B. VULNERABILITY ASSESSMENT 227

15. WINTER STORMS 230

A. HAZARD PROFILE 230

B. VULNERABILITY ASSESSMENT 234

16. CHEMICAL, BIOLOGICAL, RADIOLOGICAL, AND NUCLEAR (CBRN) 238

A. HAZARD PROFILE 238

B. VULNERABILITY ASSESSMENT 244

17. CYBER THREATS 248

A. HAZARD PROFILE 248

B. VULNERABILITY ASSESSMENT 252

18. INFRASTRUCTURE FAILURES 254

A. HAZARD PROFILE 254

B. VULNERABILITY ASSESSMENT 264

LIST OF FIGURES

FIGURE 3.1.1: RISK ASSESSMENT PROCESS 45

FIGURE 3.3.2: RISK ASSESSMENT DIAGRAM 52

FIGURE 3.4.3: THE FIVE BOROUGHS OF NEW YORK CITY 55

FIGURE 3.4.4: NEW YORK CITY TOPOGRAPHY, INCLUDING THE HIGHEST POINTS FOR EACH BOROUGH 56

FIGURE 3.4.5 : GEOLOGICAL LANDFORMS OF NEW YORK CITY 57

FIGURE 3.4.6: NEW YORK CITY DEPARTMENT OF PARKS & RECREATION PARK SYSTEM 58

FIGURE 3.4.7: NEW YORK CITY STREET TREE DENSITY 60

FIGURE 3.4.8: NEW YORK CITY POPULATION DENSITY BY CENSUS TRACT 62

FIGURE 3.4.9: NEW YORK CITY POPULATION OVER THE AGE OF 65 BY CENSUS TRACT 63

FIGURE 3.4.10: NEW YORK CITY POPULATION UNDER THE AGE OF 5 BY CENSUS TRACT 63

FIGURE 3.4.11: PERCENTAGE OF NEW YORK CITY POPULATION BELOW THE FEDERAL POVERTY LEVEL BY CENSUS TRACT 64

FIGURE 3.4.12: CONCENTRATIONS OF LINGUISTICALLY ISOLATED NEW YORKERS BY CENSUS TRACT 65

FIGURE 3.4.13: BRONX COMMUNITY DISTRICTS AND NEIGHBORHOODS 67

FIGURE 3.4.14: BROOKLYN COMMUNITY DISTRICTS AND NEIGHBORHOODS 68

FIGURE 3.4.15: MANHATTAN COMMUNITY DISTRICTS AND NEIGHBORHOODS 68

FIGURE 3.4.16: QUEENS COMMUNITY DISTRICTS AND NEIGHBORHOODS 69

FIGURE 3.4.17: STATEN ISLAND COMMUNITY DISTRICTS AND NEIGHBORHOODS 70

FIGURE 3.4.18: LAND USE IN NEW YORK CITY 73

FIGURE 3.4.19: PRIMARY LAND USE IN THE BRONX 74

FIGURE 3.4.20: PRIMARY LAND USE IN BROOKLYN 75

FIGURE 3.4.21: PRIMARY LAND USE IN MANHATTAN 76

FIGURE 3.4.22: PRIMARY LAND USE IN QUEENS 77

FIGURE 3.4.23: PRIMARY LAND USE IN STATEN ISLAND 78

FIGURE 3.4.24: NEW YORK CITY BUILDINGS BY CONSTRUCTION TYPE 81

FIGURE 3.4.25: NEW YORK CITY BUILDINGS BY AGE 81

FIGURE 3.4.26: MARKET VALUE OF BUILDINGS IN NEW YORK CITY 81

FIGURE 3.4.27: NEW YORK CITY RAIL NETWORK 86

FIGURE 3.4.28: MAJOR ELEMENTS OF THE NEW YORK CITY ROAD NETWORK 87

FIGURE 3.4.29: AIR AND WATER TRANSPORTATION ASSETS IN NEW YORK CITY 87

FIGURE 3.4.30: NEW YORK CITY'S WATER SUPPLY SYSTEM 89

FIGURE 3.4.31: WASTEWATER TREATMENT PLANTS IN NEW YORK CITY 90

FIGURE 3.4.32: EMERGENCY SERVICE PROVIDERS IN NEW YORK CITY 91

FIGURE 3.4.33: HEALTHCARE FACILITIES IN NEW YORK CITY 91

FIGURE 3.4.34: COLLEGES IN NEW YORK CITY 92

FIGURE 3.4.35: PRIVATE SCHOOLS IN NEW YORK CITY 92

FIGURE 3.4.36: PUBLIC SCHOOLS IN NEW YORK CITY 92

FIGURE 3.4.37: MAJOR CULTURAL FACILITIES IN NEW YORK CITY 93

FIGURE 3.4.38: FUTURE FLOOD MAPS FOR THE 2020S AND 2050S 95

FIGURE 3.4.39: PERCENT CHANGE IN POPULATION PER CENSUS TRACT 2000 TO 2010 97

FIGURE 3.4.40: NEW YORK CITY POPULATION, 2010-2040 97

FIGURE 3.4.41: NEW YORK CITY POPULATION BY BOROUGH, 2010-2040 98

FIGURE 3.4.42: NEW YORK CITY 65 AND OVER POPULATION BY BOROUGH, 2010-2040 98

FIGURE 3.4.43: NEW YORK CITY SCHOOL-AGE POPULATION (AGES 5 TO 17) BY BOROUGH, 2010-2040 99

FIGURE 3.4.44: CITY-INITIATED REZONINGS SINCE 2002 100

FIGURE 3.5.45: SHORELINE CHANGE FOR ANNANDALE, STATEN ISLAND, 1924 TO 2012 107

FIGURE 3.5.46: BROOKLYN COASTAL EROSION HAZARD AREAS 107

FIGURE 3.5.47: QUEENS COASTAL EROSION HAZARD AREAS 107

FIGURE 3.5.48: STATEN ISLAND COASTAL EROSION HAZARD AREAS 107

FIGURE 3.6.49: PRIMARY HAZARDS OF TROPICAL CYCLONES 111

FIGURE 3.6.50: COMBINED EFFECTS OF STORM SURGE, TIDE, AND WAVE ACTION 112

FIGURE 3.6.51: NEW YORK BIGHT WITH A HYPOTHETICAL STORM APPROACHING NEW JERSEY 113

FIGURE 3.6.52: NEW YORK CITY STORM SURGE INUNDATION ZONES 116

FIGURE 3.6.53: STORM SURGE INUNDATION ZONES WITH SELECTED INUNDATION DEPTHS FOR STORM CATEGORIES 116

FIGURE 3.6.54: TROPICAL STORM AND HURRICANE TRACKS WITHIN A 100-MILE RADIUS OF NEW YORK CITY 1851 TO 2013 119

FIGURE 3.6.55: HAZUS-MH RESULTS FOR ANNUALIZED LOSSES TO BUILDINGS DUE TO WIND FROM A COASTAL STORM, BY CENSUS TRACT 124

FIGURE 3.7.56: CONCEPTUAL MODEL OF VULNERABILITY DURING AN INFLUENZA PANDEMIC 130

FIGURE 3.7.57: DENSITY OF POPULATIONS WITH VULNERABILITY TO INFLUENZA PANDEMIC 130

FIGURE 3.7.58: CONCEPTUAL VULNERABILITY MATRIX 135

FIGURE 3.8.59: NEW YORK STATE DROUGHT MANAGEMENT REGIONS 139

FIGURE 3.8.60: DROUGHT IMPACTS ON SOCIAL, ECONOMIC, BUILT, NATURAL, AND FUTURE ENVIRONMENTS142

FIGURE 3.9.61: NEW YORK STATE SOIL CLASSIFICATIONS 148

FIGURE 3.9.62: ADJUSTED USGS 0.2 SEC SA FOR NEW YORK CITY (SOURCE: NYS OEM, 2011) 148

FIGURE 3.9.63: EARTHQUAKE PEAK GROUND ACCELERATION (% GRAVITY) 2% PROBABILITY OF EXCEEDANCE IN 50 YEARS 149

FIGURE 3.9.64: LOCATION OF EARTHQUAKES IN NEW YORK CITY AND SURROUNDING AREAS 1973 TO 2012 150

FIGURE 3.9.65: HAZUS-MH EARTHQUAKE DAMAGE STATES 153

FIGURE 3.10.66: NUMBER OF DAYS WITH TEMPERATURES OF 90°F OR HIGHER AT CENTRAL PARK, 1870 TO 2013 161

FIGURE 3.10.67: NEW YORK CITY THERMAL IMAGERY TAKEN AUGUST 18, 2009 162

FIGURE 3.10.68: NEW YORK CITY VEGETATIVE COVER 162

FIGURE 3.10.69: ANNUAL WEATHER FATALITIES IN THE UNITED STATES 165

FIGURE 3.11.70: STORM SURGE HEIGHT, WAVE RUN UP, STORM TIDE, AND TIDE 173

FIGURE 3.11.71: BRONX 100-YEAR FLOODPLAIN 176

FIGURE 3.11.72: BROOKLYN 100-YEAR FLOODPLAIN 176

FIGURE 3.11.73: MANHATTAN 100-YEAR FLOODPLAIN 176

FIGURE 3.11.74: QUEENS 100-YEAR FLOODPLAIN 177

FIGURE 3.11.75: STATEN ISLAND 100-YEAR FLOODPLAIN 177

FIGURE 3.11.76: SANDY INUNDATION AREA 178

FIGURE 3.11.77: NFIP POLICIES 180

FIGURE 3.11.79: NFIP REPETITIVE LOSS PROPERTIES 180

FIGURE 3.11.78: NFIP POLICY CLAIMS 180

FIGURE 3.11.80: HAZUS-MH RESULTS FOR ECONOMIC LOSSES FROM A 100-YEAR FLOOD IN NEW YORK CITY 193

FIGURE 3.11.81: HAZUS-MH RESULTS FOR ECONOMIC LOSSES FROM A 100-YEAR FLOOD IN THE BRONX 194

FIGURE 3.11.82: HAZUS-MH RESULTS FOR ECONOMIC LOSSES FROM A 100-YEAR FLOOD IN BROOKLYN 194

FIGURE 3.11.83: HAZUS-MH RESULTS FOR ECONOMIC LOSSES FROM A 100-YEAR FLOOD IN MANHATTAN 194

FIGURE 3.11.84: HAZUS-MH RESULTS FOR ECONOMIC LOSSES FROM A 100-YEAR FLOOD IN QUEENS 195

FIGURE 3.11.85: HAZUS-MH RESULTS FOR ECONOMIC LOSSES FROM A 100-YEAR FLOOD IN STATEN ISLAND 195

FIGURE 3.11.86: PARKS AND OPEN SPACE IN THE 100-YEAR FLOODPLAIN 196

FIGURE 3.11.87: PROJECTED FUTURE 100-YEAR FLOODPLAIN 198

FIGURE 3.12.88: HURRICANE SANDY'S PATH (SOURCE: NOAA). 201

FIGURE 3.12.89: SATELLITE IMAGE SHOWING HURRICANE SANDY ENGULFING MUCH OF THE EASTERN UNITED STATES AND SOUTHERN CANADA 202

FIGURE 3.12.90: HURRICANE SANDY INUNDATION IN NEW YORK CITY 203

FIGURE 3.12.91: TRANSPORTATION INFRASTRUCTURE INUNDATED DURING HURRICANE SANDY 206

FIGURE 3.12.92: HEALTHCARE FACILITIES INUNDATED DURING HURRICANE SANDY 206

FIGURE 3.12.93: SCHOOLS AND CULTURAL FACILITIES INUNDATED DURING HURRICANE SANDY 207

FIGURE 3.13.94: HAIL SIZE AND RELATED DAMAGES 214

FIGURE 3.13.95: TRI-STATE TORNADO CLIMATOLOGY, 1950 TO 2012 216

FIGURE 3.13.96: WIND ZONES IN THE UNITED STATES 217

FIGURE 3.13.97: WIND ZONES IN NEW YORK STATE 217

FIGURE 3.14.98: ANNUAL DISTRIBUTION OF WILDFIRES IN NEW YORK CITY BASED ON FDNY TEMPORAL ANALYSIS AT GATEWAY NATIONAL RECREATION AREA 226

FIGURE 3.14.99: SERIOUS WILDFIRES IN NEW YORK CITY BY BOROUGH 1996 TO 2013 227

FIGURE 3.14.100: AREA COVERED BY STATEN ISLAND COMMUNITY WILDFIRE PROTECTION PLAN 228

FIGURE 3.15.101: WINTER WEATHER DEFINITIONS 232

FIGURE 3.15.102: NORTHEAST SNOWFALL IMPACT SCALE (NEIS) 233

FIGURE 3.16.103: NFPA 704M RATING SYSTEM FOR CHEMICAL HAZARDS 242

FIGURE 3.16.104: PROBABILITY VS. IMPACT FROM DIFFERENT CATEGORIES OF CBRN RELEASES 243

FIGURE 3.17.105: THREAT ACTOR CATEGORIES 2008 TO 2012 251

FIGURE 3.17.106: VICTIMS OF CYBER ATTACKS BY INDUSTRY IN 2012 252

FIGURE 3.18.107: ELECTRICITY DISTRIBUTION SYSTEM TYPES 261

LIST OF TABLES

TABLE 3.2.1: NATURAL HAZARDS CONSIDERED FOR INCLUSION IN THE 2014 HMP 47

TABLE 3.2.2: NON-NATURAL HAZARDS CONSIDERED FOR INCLUSION IN THE 2014 HMP 48

TABLE 3.2.3: NEW YORK CITY HAZARD SELECTION WORKSHEET RESULTS 49

TABLE 3.3.4: RETURN PERIODS WITH ANNUAL CHANCE OF OCCURRENCE 53

TABLE 3.4.5: SELECTED WETLANDS IN THE NEW YORK CITY REGION 60

TABLE 3.4.6: NEW YORK CITY POPULATION DENSITY BY BOROUGH 61

TABLE 3.4.7: NEW YORK CITY POPULATION BY AGE AND BOROUGH 61

TABLE 3.4.8: NEW YORK CITY POPULATION BELOW FEDERAL POVERTY LEVEL BY AGE 64

TABLE 3.4.9: NEW YORKERS WHO SPEAK ENGLISH LESS THAN "VERY WELL" BY BOROUGH 65

TABLE 3.4.10: NEW YORKERS WITH DISABILITIES BY AGE AND BOROUGH 66

TABLE 3.4.11: NEW YORK CITY EMPLOYMENT BY INDUSTRY AUGUST 2013 70

TABLE 3.4.12: SUMMARY OF NEW YORK CITY LAND USE 72

TABLE 3.4.13: LAND USE IN THE BRONX 74

TABLE 3.4.14: LAND USE IN BROOKLYN 75

TABLE 3.4.15: LAND USE IN MANHATTAN 76

TABLE 3.4.16: LAND USE IN QUEENS 77

TABLE 3.4.17: LAND USE IN STATEN ISLAND 78

TABLE 3.4.18: NEW YORK CITY NUMBER OF BUILDINGS BY BOROUGH SUMMARY DATA 79

TABLE 3.4.19: NEW YORK CITY BUILDING STOCK SUMMARY DATA 80

TABLE 3.4.20: TELECOMMUNICATIONS COMPANIES IN NEW YORK CITY 85

TABLE 3.4.21: NEW YORK CITY RAIL RIDERSHIP 86

TABLE 3.4.22: NPCC SEA LEVEL RISE PROJECTIONS 2013 94

TABLE 3.4.23: NPCC PROJECTIONS FOR HEAT WAVES AND COLD EVENTS 2013 95

TABLE 3.4.24: NPCC PROJECTIONS FOR PRECIPITATION AND INTENSE PRECIPITATION 2013 96

TABLE 3.5.25: ACREAGE AND BUILDINGS WITHIN NYS DEC-MAPPED COASTAL EROSION HAZARD AREAS 108

TABLE 3.6.26: SAFFIR-SIMPSON HURRICANE WIND SCALE, INCLUDING TROPICAL STORMS 115

TABLE 3.6.27: COASTAL STORMS AFFECTING NEW YORK CITY 1785 TO 2012 117

TABLE 3.6.28: NEW YORK CITY RESIDENTS IN STORM SURGE INUNDATION ZONES 120

TABLE 3.6.29: DAMAGE STATES FOR RESIDENTIAL STRUCTURES 122

TABLE 3.6.30: HAZUS-MH CALCULATION OF APPROXIMATE NUMBER OF BUILDINGS DAMAGED DUE TO WIND FROM A COASTAL STORM, BY RETURN PERIOD 122

TABLE 3.6.31: HAZUS-MH CALCULATION OF ECONOMIC LOSSES DUE TO WIND FROM A COASTAL STORM, BY RETURN PERIOD 123

TABLE 3.6.32: HAZUS-MH CALCULATION OF ANNUALIZED ECONOMIC LOSSES DUE TO WIND FROM A COASTAL STORM, BY BOROUGH 123

TABLE 3.6.33: CRITICAL ASSETS WITHIN STORM SURGE INUNDATION ZONES 125

TABLE 3.7.34: SELECTED DISEASE OUTBREAKS IN NEW YORK CITY 1668 TO 2013 132

TABLE 3.8.35: DROUGHTS IN NEW YORK CITY 1963 TO 2003 140

TABLE 3.9.36: MMI SCALE RATING 146

TABLE 3.9.37: APPROXIMATE RELATIONSHIP BETWEEN MMI AND PGA 147

TABLE 3.9.38: EARTHQUAKES FELT IN NEW YORK CITY 1737 TO 2013 151

TABLE 3.9.39: NUMBER OF BUILDINGS DAMAGED FROM EARTHQUAKES BY RETURN PERIOD FOR NEW YORK CITY 154

TABLE 3.9.40: SUMMARY OF DETERMINISTIC RESULTS OF NYCEM STUDY 155

TABLE 3.9.41: SUMMARY OF PROBABILISTIC RESULTS OF NYCEM STUDY 155

TABLE 3.10.42: NWS HEAT INDEX 159

TABLE 3.10.43: HEALTH HAZARDS ASSOCIATED WITH HEAT INDEX VALUES 159

TABLE 3.10.44: NWS EXTREME HEAT PRODUCTS FOR THE NEW YORK CITY REGION 160

TABLE 3.10.45: NWS WIND-CHILL CHART 160

TABLE 3.10.46: NWS WIND-CHILL PRODUCTS FOR THE NEW YORK CITY REGION 160

TABLE 3.10.47: EXTREME TEMPERATURES IN NEW YORK CITY 1995 TO 2013 163

TABLE 3.10.48: HOSPITAL ADMISSIONS AND ED VISITS FOR HEAT ILLNESS AND HEAT STROKE DEATHS, 2001-2011 166

TABLE 3.10.49: QUANTITATIVE CHANGES IN EXTREME TEMPERATURE EVENTS 169

TABLE 3.11.50: NATIONAL WEATHER SERVICE FLOOD CATEGORIES 174

TABLE 3.11.51: FIRM FLOOD ZONE CATEGORIES 175

TABLE 3.11.52: REPETITIVE LOSS CLAIMS BY HOUSING TYPE (2012 - 2013) 179

TABLE 3.11.53: SELECTED FLOOD EVENTS IN NEW YORK CITY 1993 TO 2013 181

TABLE 3.11.54: POPULATION AND HOUSEHOLDS IN 100-YEAR FLOODPLAIN 187

TABLE 3.11.55: POPULATION BY AGE GROUP WITHIN 100-YEAR FLOODPLAIN 188

TABLE 3.11.56: POPULATION BELOW POVERTY LEVEL WITHIN 100-YEAR FLOODPLAIN 188

TABLE 3.11.57: BUILDING TYPE AND AGE WITHIN 100-YEAR FLOODPLAIN 189

TABLE 3.11.58: CRITICAL ASSETS IN THE 100-YEAR FLOODPLAIN 190

TABLE 3.11.59: HAZUS-MH CALCULATION OF APPROXIMATE NUMBER OF BUILDINGS DAMAGED FROM A 100-YEAR FLOOD, BY BOROUGH 192

TABLE 3.11.60: HAZUS-MH CALCULATION OF DIRECT ECONOMIC LOSSES FROM A 100-YEAR FLOOD, BY BOROUGH AND DAMAGE TYPE 192

TABLE 3.11.61: PARKS IN THE 100-YEAR FLOODPLAIN 196

TABLE 3.11.62: SEA LEVEL RISE IN THE 2020S AND 2050S 198

TABLE 3.12.63: CRITICAL ASSETS IN HURRICANE SANDY INUNDATION AREA 205

TABLE 3.12.64: PERCENTAGE OF BUILDINGS IN HURRICANE SANDY INUNDATION ZONE DAMAGED DUE TO FLOODING, BY BOROUGH 207

TABLE 3.12.65: DIRECT ECONOMIC LOSSES DUE TO FLOODING FROM HURRICANE SANDY, BY BOROUGH 207

TABLE 3.13.66: COMPARISON OF FUJITA (F-SCALE) AND ENHANCED FUJITA (EF-SCALE) SCALES 214

TABLE 3.13.67: BEAUFORT WIND SCALE (NOAA, 2013) 215

TABLE 3.13.68: SELECTED SEVERE WEATHER EVENTS 1974 TO 2013 218

TABLE 3.14.69: SELECT SIGNIFICANT WILDFIRES IN NEW YORK CITY 2008 TO 2012 228

TABLE 3.15.70: INCHES OF MEASURED SNOWFALL DECEMBER 26 AND 27, 2010 233

TABLE 3.15.71: SELECTED MAJOR WINTER STORMS IN NEW YORK CITY 1798 TO 2013 234

TABLE 3.16.72: SYMPTOMS OF RADIATION EXPOSURE 242

TABLE 3.16.73: SELECTED CBRN RELEASES IN NEW YORK CITY 1973 TO 2013 245

TABLE 3.17.74: MAJOR TYPES OF CYBER ATTACKS AND ATTACK VECTORS 250

TABLE 3.17.75: PERPETRATOR CATEGORIES FOR CYBER ATTACKS **251**

TABLE 3.17.76: SIGNIFICANT CYBER INCIDENTS AFFECTING NEW YORK CITY 2010 TO 2013 **253**

TABLE 3.18.77: SELECTED INFRASTRUCTURE FAILURES IN NEW YORK CITY 1928 TO 2013 **262**

1 . Introduction

What would happen if a hazard event occurred in New York City? That is the fundamental question that fuels the hazard mitigation planning process—and it is also the question that this chapter of the report begins to address. The first step in planning for hazards is to assess the risks from them. This risk assessment involves evaluating the vulnerability of people, buildings, and infrastructure to estimate the potential loss of life, personal injury, economic losses, and property damage that may result.

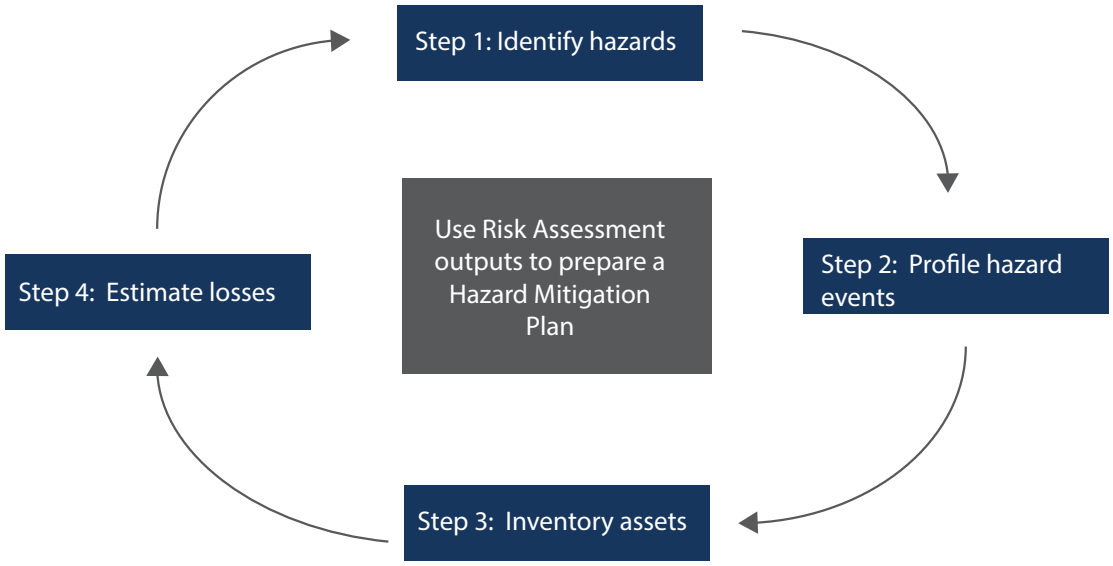
- Identify which hazards pose a serious risk to New York City
- Describe what these hazards can do to physical, social, and economic assets of New York City
- Identify which areas of New York City are most vulnerable to damage from these hazards
- Estimate losses that may result from the identified hazards

A. The Risk Assessment Process

To meet Federal Emergency Management Agency (FEMA) and New York State Division of Homeland Security and Emergency Services (NYS DHSES) requirements, the Hazard Mitigation Planning Team (Planning Team), composed of representatives of the New York City Office of Emergency Management (OEM), Department of City Planning (DCP), and Mayor's Office of Long-Term Planning and Sustainability (OLTPS), used a risk assessment process consistent with the procedures and steps presented in FEMA's *Local Mitigation Plan Review Guide* (2011) (website link provided at the end of Chapter 2). The four steps in the risk assessment process are:

The Planning Team's four-step risk assessment process is illustrated in Figure 3.1.1: Risk Assessment Process.

Figure 3.1.1: Risk Assessment Process



B. FEMA and NYS OEM Requirements Addressed in this Chapter

New York City's Mitigation Strategy was developed consistent with the process and steps presented in the FEMA *Local Mitigation Plan Review Guide* (2011) (website link provided at the end of chapter 2). This chapter's presentation of the Risk Assessment satisfies the following FEMA requirements:

- **FEMA Requirement 44 CFR §201.6(c)(2)(i):** [The risk assessment ***shall*** include a] description of the type, location and extent of all natural hazards that can affect the jurisdiction. The plan shall include information on previous occurrences of hazard events and on the probability of future hazard events.
- **FEMA Requirement 44 CFR §201.6(c)(2)(ii):** [The risk assessment ***shall*** include a] description of the jurisdiction's vulnerability to the hazards described in paragraph (c)(2)(i) of this section. This description shall include an overall summary of each hazard and its impact on the community. All plans approved after October 1, 2008 must also address NFIP insured structures that have been repetitively damaged by floods. The plan should describe vulnerability in terms of:
- **FEMA Requirement 44 CFR §201.6(c)(2)(ii)(A)**: The types and numbers of existing and future buildings, infrastructure, and critical facilities located in the identified hazard areas.
- **FEMA Requirement 44 CFR §201.6(c)(2)(ii)(B):** An estimate of the potential dollar losses to vulnerable structures identified in … this section and a description of the methodology used to prepare the estimate.
- **FEMA Requirement 44 CFR §201.6(c)(2)(ii)(C)**: Providing a general description of land uses and development trends within the community so that mitigation options can be considered in future land use decisions.

The following DHSES *Hazard Mitigation Planning Standards* (2012) (website link provided at the end of chapter 2) are also addressed in this chapter:

- **NYS Requirement §F2:** Plans developed with State OEM-administered funds ***must*** document that proposed (or already implemented) projects will protect facilities to a 500-year flood event or the actual worst-damage scenario, whichever is greater.
- **NYS Requirement §F6:** Plans developed with State OEM-administered funds ***must*** include climate change information within their discussion of these hazards and ***must*** contain strategies and projects to address them.

2. Hazard Identification

The first step in the risk assessment process is to identify hazards to include in the plan. To initiate this determination, the Planning Team, with input from the Mitigation Planning Council Steering Committee (MPCSC), identified an initial list of hazards that could potentially impact the city and then selected the hazards of greatest concern for further research and analysis.

A. Potential Hazards

Since New York is such a large and dynamic city, it faces a broad spectrum of hazards, many of which are also caused or exacerbated by human activities. During the hazard identification process for the 2014 Natural Hazard Mitigation Plan (HMP), the Planning Team considered the full range of natural hazards identified in the 2011 New York State Multi-Hazard Mitigation Plan and made a few minor alterations, which included wording and organization, to produce a comprehensive natural hazard list. For this 2014 plan update, the Planning Team decided to expand upon this list, adding "non-natural" hazards to the required natural hazards.

To identify a preliminary list of non-natural hazards, as well as develop and refine its working list of natural hazards, the Planning Team reviewed existing plans from other local, regional, and national jurisdictions. The Planning Team also reviewed historic activations of the OEM Emergency Operations Center (EOC). Table 3.2.1 lists the full range of natural hazards that the Planning Team considered for inclusion in the HMP, and Table 3.2.2 lists the full range of non-natural hazards.

Table 3.2.1: Natural Hazards Considered for Inclusion in the 2014 HMP

Hazard	Description
Coastal erosion	Loss or displacement of land along the coastline due to the action of wind, waves, currents, tides, runoff of surface waters, or groundwater seepage
Coastal storms	Includes tropical cyclones (tropical storms and hurricanes) and nor'easters
Dam failure	An uncontrolled release of impounded water resulting in downstream flooding
Disease outbreaks	When disease cases exceed what would normally be expected in a defined community, geographic area, or season
Drought	A prolonged period with below-average precipitation
Earthquake	A sudden, rapid shaking of the earth caused by the breaking and shifting of rock beneath the earth's surface
Extreme temperatures	*Extreme Heat:* Summertime temperatures that are well above average, usually combined with high levels of humidity. A heat wave is defined as three or more days with temperatures at or above 90°F. *Extreme Cold:* Wintertime temperatures that drop well below normal in an area
Floods	A general and temporary condition of partial or complete inundation on normally dry land
Hailstorms	Shower-like precipitation in the form of irregularly shaped ice pellets falling from a thunderstorm
Landslides	The downward and outward movement of slope-forming materials reacting to the force of gravity
Land subsidence	Depressions, cracks, and sinkholes in the earth's surface, which can threaten people and property

Hazard	Description
Tornadoes/windstorms	*Tornadoes:* Local atmospheric storms, generally of short duration, formed by winds rotating at very high speeds, usually in a counterclockwise direction, with vortices visible to the observer as whirlpool-like columns of winds rotating about a hollow cavity or funnel. *Windstorms:* Non-rotating, straight-line winds that can knock down trees and power lines and cause damage to structures
Wildfires	Uncontrolled burning in grasslands, brush, or woodlands that can eventually spread to the built environment
Winter storms	Ice storms, heavy snow, and blizzards, often accompanied by extreme cold. Heavy snow generally means snowfall accumulating to 6 inches or more in 12 hours or less, or snowfall accumulating to 8 inches or more in 24 hours or less. A blizzard has winds of 35 miles per hour or more with snow and blowing snow, reducing visibility to less than 1/4 mile for at least three hours

Table 3.2.2: Non-natural Hazards Considered for Inclusion in the 2014 HMP

Hazard	Description
Air contamination	Poor air quality resulting from a high concentration of primarily industrial pollutants (including particulate matter and ozone) near the ground
Aviation incidents	Accidents involving aircraft departing from or arriving at Kennedy or LaGuardia Airports that cause or have the potential to cause injury or loss of life
Building collapses/fires/explosions	Damage to or destruction of a building resulting from collapse, fire, or explosion
Civil unrest	A public crisis that occurs without warning and may adversely impact a significant portion of the population
Cyber threats	An adverse event in an information system or network in which the digital infrastructure of a person or organization is compromised
Release of chemical, biological, radiological, or nuclear materials (CBRN)	A situation in which hazardous materials are released into the environment, causing a threat to human health and safety
Infrastructure failure	Failure of infrastructure systems—including transportation, water, and wastewater—to perform their intended functions.
Utility disruptions	Disruptions to essential utilities, including energy (electric, gas and steam) and communications.

B. Hazard Selection Process

i. Existing Plans and Procedures

When considering which hazards to include in the HMP, the Planning Team identified the City's existing emergency plans and procedures that address both natural and non-natural hazards. OEM and other City agencies have plans and procedures in place for many natural hazards, including coastal storms, drought, extreme temperatures, floods, tornadoes/windstorms, and winter storms. The Planning Team also drew from *A Stronger, More Resilient New York* (website link provided at the end of section 4), New York City's comprehensive plan with actionable recommendations for rebuilding the communities impacted by Sandy and increasing the resiliency of buildings and infrastructure citywide.

New York City also has plans in place for non-natural hazards, including various types of hazardous materials releases (chemical, biological, and radiological) and power disruptions. In addition, OEM is currently drafting an emergency plan for cyber threats. It was evident that all of these hazards can significantly affect New York City and should be included in the HMP.

ii. Hazard Selection Worksheet

The MPCSC supported the hazard identification process by completing a hazard selection worksheet. The hazard selection worksheet asked MPCSC members to indicate which hazards would affect their agencies' operations, policies, and/or physical infrastructure. Agencies were asked to indicate "Yes" if they felt strongly that the hazard posed a significant threat and "No" if they felt strongly that the hazard did not pose a significant threat. If they did not feel strongly one way or the other, they left the field blank. Since the Planning Team was involved in the initial hazard selection, OEM, DCP, and OLTPS did not fill out hazard selection worksheets.

Table 3.2.3: New York City Hazard Selection Worksheet Results

Hazard	DEP	DOT	FDNY	MTA	DOHMH	DPR	RPA	DOB	NYPD	Total Yes	Total No
Coastal erosion	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	8	0
Coastal storms	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9	0
Dam failure	No	No						No	No	0	4
Drought	Yes	No	Yes	Yes		Yes	Yes	Yes	Yes	7	1
Earthquakes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	8	0
Extreme temperatures	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9	0
Floods	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9	0
Hailstorms	No	No	Yes				Yes	No	No	2	4
Landslides	No	Yes	No					Yes	Yes	3	2
Tornadoes and windstorms	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	8	0
Land subsidence	Yes	Yes	No					Yes	No	3	2
Wildfires	Yes	No	Yes			Yes		No	Yes	4	2
Winter storms	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9	0
Air contamination	Yes	No	Yes		Yes		Yes			4	1

Hazard	DEP	DOT	FDNY	MTA	DOHMH	DPR	RPA	DOB	NYPD	Total Yes	Total No
Aviation incident	No	Yes	Yes					No	Yes	3	2
Building collapses/ fires/explosions	Yes	Yes	Yes	Yes			Yes	Yes	Yes	7	0
Civil unrest	No	Yes	Yes					Yes	Yes	4	1
Cyber threats	No	No	Yes	Yes			Yes			3	2
Disease outbreaks	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	8	0
Hazardous materials release (CBRN)	Yes	No	Yes	Yes			Yes	Yes		5	1
Utility disruption	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	8	0
Infrastructure failure*	-	-	-	-	-	-	-	-	-	-	-

Notes: *This hazard was added after the worksheet was distributed to the MPCSC

Table 3.2.3 summarizes the tally from the worksheets.A majority of Steering Committee members checked "Yes" for the following hazards: coastal erosion, coastal storms, drought, earthquakes, extreme temperatures, floods, tornadoes/windstorms, winter storms, disease outbreaks, building collapses/fires/explosions, CBRN, and utility disruptions. Other hazards listed required additional research to determine whether they should be included in the HMP. The Planning Team collected and analyzed additional data on dam failure, hailstorms, landslides, subsidence, wildfires, air contamination, aviation incidents, civil unrest, and cyber threats from newspapers, City records, the National Oceanic and Atmospheric Administration (NOAA), the National Weather Service (NWS), and FEMA databases.

After further consideration, the Planning Team decided to include wildfires and cyber threats in the final list. In addition, several new categories were created to consolidate multiple hazards from the original list; severe weather (incorporates hail and tornadoes/windstorms) and infrastructure failures (incorporates utility disruptions and damage to other types of infrastructure). Air contamination was incorporated into the extreme temperatures and CBRN hazards.

C. Eliminated Hazards

For this plan, the Planning Team chose to address only the most prevalent hazards affecting New York City and hazards for which sufficient data was available to develop a full profile. After conducting additional research, the Planning Team completely eliminated from the HMP process dam failure, landslides, land subsidence, aviation incidents, and civil unrest. Although building collapses/fires/explosions received a majority vote, these types of events are generally caused by other types of hazards (both natural and non-natural) that serve as a trigger event. After drafting a profile for this hazard, the Planning Team decided to incorporate this information into other hazard profiles.

D. Final List of New York City Hazards

Based on recommendations from the MPCSC and additional research conducted by the Planning Team, the Planning Team decided to retain 10 natural hazards and three non-natural hazards for analysis in the HMP. They are as follows:

Natural hazards:

(1) *Coastal erosion*

(2) *Coastal storms*

(3) *Disease outbreaks*

(4) *Drought*

(5) *Earthquakes*

(6) *Extreme temperatures*

(7) *Flooding*

(8) *Severe weather*

(9) *Wildfires*

(10) Winter storms

Non-natural hazards:

(1) CBRN

(2) Cyber threats

(3) Infrastructure failures

Since this plan was written shortly following Hurricane Sandy, the worst natural disaster in New York City's history, the Planning Team decided to include a retrospective analysis of this particular storm and what the City learned from it. The Sandy section is separate from the coastal storms profile.

3. Hazard Risk Assessment Organization

The risk assessments for each hazard are divided into two primary components (see Figure 3.3.2). The first component, the Hazard Profile, is a description of the hazard and the city's physical risk. The second section, the Vulnerability Assessment, is an analysis of how susceptible the city's social environment (population), built environment, natural environment, and future environment are to each hazard. The one exception to this organizational structure is the section on Hurricane Sandy because it is a description of a historic event rather than an assessment of risk from a potential hazard.

A. Hazard Profile

The Hazard Profile is divided into five subsections, as follows:

1) **Hazard Description**: a general description of the natural or non-natural hazard that can affect New York City

2) **Severity**: the strength or magnitude of the hazard, how it is measured, and the range of impacts it can have

3) **Probability**: the likelihood of the hazard occurring in New York City

4) **Location**: the geographic areas within New York City that may be most significantly affected by the hazard

5) **Historic Occurrences**: previous events of this type in New York City

This organization structure is in accordance with the requirements from FEMA, and most hazards included in this report fit these categories at least fairly well. However, complete information was not always available for every category of every hazard profile (for example, probability is generally not quantifiable for coastal erosion and most non-natural hazards).

B. Vulnerability Assessment

This Vulnerability Assessment section is divided into four subsections, as follows:

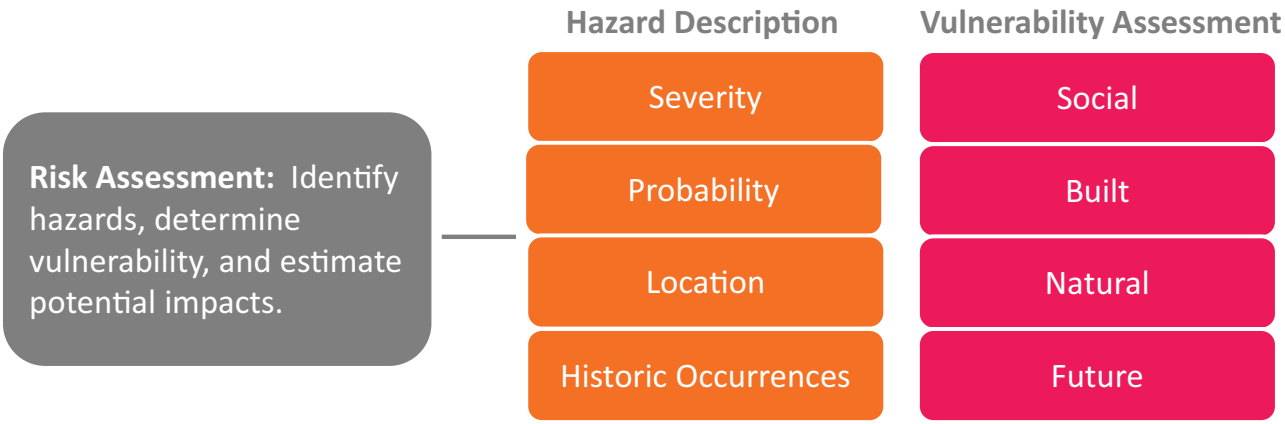
1) **Social Environment**: the hazard's effect on the general public, including public health impacts and potential fatalities, with an emphasis on vulnerable and special needs populations

2) **Built Environment**: structural vulnerabilities of the city's building stock and infrastructure. For flooding, coastal storms, and earthquakes, this section also includes a quantitative calculation of loss estimates (see i. Vulnerability Assessment Methodology, below)

3) **Natural Environment**: the hazard's impact on the natural resources, ecosystems, and recreational areas

4) **Future Environment**: how trends such as climate change, population growth, aging infrastructure, and new technology may change the risk and/or impacts of hazards in the future

Figure 3.3.2: Risk Assessment Diagram



i. Vulnerability Assessment Methodology

To conduct the vulnerability assessment, address the requirements of the Disaster Mitigation Act of 2000, and better understand the potential vulnerability and losses associated with hazards of concern, New York City used standardized tools including the HAZUS-MH modeling software, combined with local, state, and federal data.

HAZUS-MH Methodology

Hazards U.S. Multi-Hazard (HAZUS-MH) is a nationally applicable standardized methodology and software program, developed by FEMA and under contract with the National Institute of Building Sciences. The program estimates potential losses from earthquakes, hurricane winds, and floods. In HAZUS-MH, current scientific and engineering knowledge is coupled with Geographic Information Systems (GIS) technology to produce estimates of hazard-related damage before or after a disaster occurs.

Potential loss estimates analyzed in HAZUS-MH include:

- **Physical damage** to residential and commercial buildings, schools, critical facilities, and infrastructure
- **Economic loss**, including lost jobs, business interruptions, and repair and reconstruction costs

HAZUS-MH is designed to generate estimates of hazard-related damage to a city or a region from a hypothetical "hazard event" (that is, an earthquake, hurricane, or flood) of a fixed severity and location, also known as a "deterministic" event. This type of analysis can also be used to estimate damages from a historic event. Another type of analysis models the damage caused by an event that is likely to occur over a given period of time (return period), also known as a "probabilistic" event." For example, HAZUS-MH can estimate the damage caused by an earthquake that is likely to occur once every 500 years (which has a 1 in 500 or 0.2% chance of occurring in any given year, see Table 3.3.4). For all HAZUS-MH models, the focus is on damage to buildings, quantified as a measure of building damage counts, damage states, and dollar losses. Buildings are assumed to have a lifespan of 50 years.

Table 3.3.4: Return Periods with Annual Chance of Occurrence

Return period (years)	Chance of occurrence in any given year (%)
10	10
20	5
30	3.33
50	2
100	1
200	0.5
250	0.4
500	0.2
1,000	0.1
2,500	0.04

In addition, HAZUS-MH provides an estimate of annualized economic building losses. These values are averages based on the total estimated losses over the entire simulation period divided by the total number of years in the simulation. For example, if a particular location is expected to suffer $20 billion in damage from hurricanes over a 20-year period, the annualized economic losses would be $1 billion. The formula for calculating annualized economic losses must take into account a wide range of possible scenarios and probabilities.

HAZUS-MH uses demographic and general building stock (GBS) data to estimate hazard-related damage. The GBS data input into HAZUS-MH is a summary of building counts, values, construction types, and uses by census block or tract. New York City supplemented this default data with a refined set of GBS data because an initial review found that for the city as a whole, the default GBS data provided with HAZUS-MH did not adequately reflect actual conditions. To refine the default GBS dataset, OEM provided an updated set of building data to Applied Research Associates, Inc. (ARA), a private consulting firm which is one of the developers of the HAZUS-MH software. This dataset consisted of Property Land Use Tax lot Output (MapPLUTO) from the Department of City Planning (DCP) and mass appraisal data from the Department of Finance (DOF). ARA converted this dataset to a format that was usable by HAZUS-MH, classifying all structures according to the building type and occupancy classes required

by the software. Additionally, for this update of the HMP, FEMA personnel assisted OEM by reformatting the revised GBS data for use with the latest version of HAZUS-MH (version 2.1). The resulting census block-based dataset provided a much more accurate starting point for subsequent analyses. Due to different methodologies and variations in data sets, total citywide building counts will differ from the numbers listed in Section 4: New York City's Hazard Environment, Table 3.4.18.

It is important to note that while the HAZUS-MH analyses provide a good starting point for loss and damage estimation, they are approximate predictions. There is uncertainty inherent in any predictive model, and HAZUS-MH is no exception. This software is not meant for site-specific damage analysis. Furthermore, since HAZUS is an asset damage model, it generally does not capture impacts to networks, such as utilities, telecommunications, transportation, and liquid fuel systems. The City has created models to better understand the interdependencies of these systems and has discovered that it is more effective and cost efficient to target investments toward key critical facilities. These upgrades will reduce the impact of extreme events and increase the recovery time.

Despite its limitations, the results of the HAZUS-MH analyses help shed light on the expected distribution and level of losses for different areas. Although building damage counts may not always reflect exact conditions on the ground, especially when analyzing small areas, percentages of buildings damaged and losses over the entire study area should provide a relatively accurate picture of the level of damage that might be expected to occur on a citywide scale.

Methodology for Assessing Hazards Not Covered by HAZUS-MH

Hazards included in this report that cannot be analyzed using HAZUS-MH are coastal erosion, drought, extreme temperatures, severe weather, wildfires, winter storms, CBRN, cyber threats, and infrastructure failures. Potential impacts on vulnerable populations and infrastructure were evaluated using the best available data to assess risks for these hazards and to help identify appropriate mitigation efforts.

While this risk assessment relies on the best available data and methodologies, uncertainties are inherent in any loss-estimation methodology. These uncertainties arise in part from incomplete scientific knowledge concerning hazards and their effects on the social, built, natural, or future environment. They can also result from the unique nature, geographic extent, and severity of each hazard. Therefore, potential exposure and loss estimates should be considered approximate.