Hazus Inventory Technical Manual

Hazus 6.1

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FEMA

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Acronyms and Abbreviations

Acronym/Abbreviation	Definition
ACS	American Community Survey
AEBM	Advanced Engineering Building Module
AGR	Agriculture
ASCE	American Society of Civil Engineers
ATC	Applied Technology Council
BCAT	Building Code Adoption Tracking
BCS	Building Codes Save
BEA	Bureau of Economic Analysis
BFE	Base Flood Elevation
BID	Building Identification Number
BLS	Bureau of Labor Statistics
BUR	Built-Up Roof
C	Concrete
CBECS	Commercial Buildings Energy Consumption Survey
CCD	Community College District
CDE	California Department of Education
CDMS	Comprehensive Data Management System
CECB	Concrete, Engineered Commercial Building
CEIWR	USACE Institute for Water Resources
CERB	Concrete, Engineered Residential Building
CID	Community Identification Number
CIS	Community Information System
COM	Commercial
CONUS	Continental United States
CPI	Consumer Price Index
DOE	Department of Energy
EDU	Education

Acronym/Abbreviation	Definition
EF	Essential Facilities
EIA	Energy Information Administration
EOC	Emergency Operations Center
EPA	Environmental Protection Agency
EQ	Earthquake
ESRI	Environmental Systems Research Institute
FCC	Federal Communications Commission
FEMA	Federal Emergency Management Agency
FHBM	Flood Hazard Boundary Map
FIPS	Federal Information Processing Standards
FIRM	Flood Insurance Rate Map
FFHAG	First Floor Height Above Grade
FL	Flood
ft	Feet
ft^2	Square Feet
FHWA	Federal Highway Administration
GBS	General Building Stock
GCS	Geographic Coordinate System
GEOID	Geographic Identifiers
GHIN	Global Hazards Information Network
GIS	Geographic Information Systems
GOV	Government
GS	Ground Shaking
HC	High-Code
HIFLD	Homeland Infrastructure Foundation-Level Data
hp	Horsepower
HPL	High Potential Loss
HS	Special High-Code
HU	Hurricane

Acronym/Abbreviation	Definition
HUC	Hydrologic Unit Code
HUD	U.S. Department of Housing and Urban Development
IBC	International Building Code
IND	Industrial
IPUMS	Integrated Public Use Series
IR	Income Ratio
IRC	International Residential Code
km	Kilometer
kV	Kilovolt
kW	Kilowatt
Lidar	Light detection and ranging
LEHD	Longitudinal Household Employer Dynamic Database
LC	Low-Code
LS	Special Low-Code
M	Masonry
MC	Moderate-Code
MCE	Maximum Considered Earthquake
MECB	Masonry, Engineered Commercial Building
MERB	Masonry, Engineered Residential Building
MGD	Million Gallons per Day
MH	Mobile Homes or Manufactured Housing
MLR	Masonry, Low-Rise
MMcf	Million Cubic Feet
MMUH	Masonry, Multi-Unit Housing
MPP	Map Production Pro
MR	Maintenance Release
MRLC	Multi-Resolution Land Characteristics Consortium
MS	Special Moderate-Code
MSF	Masonry, Single-family

Acronym/Abbreviation	Definition
MTFCC	Master Address File (MAF)/TIGER Feature Class Code
MW	Megawatts
NAICS	North American Industry Classification System
NBI	National Bridge Inventory
NEHRP	National Earthquake Hazards Reduction Program
NFHL	National Flood Hazard Layer
NFIP	National Flood Insurance Program
NGA	National Geospatial-Intelligence Agency
NHGIS	National Historical Geographic Information System
NHRAP	FEMA Natural Hazards Risk Assessment Program
NIBS	National Institute of Building Sciences
NLCD	National Land Cover Database
NOAA	National Atmospheric and Oceanic Association
NSI	National Structure Inventory
OCONUS	Outside of the Continental United States
ORNL	Oak Ridge National Laboratory
PC	Precast Concrete
PC	Pre-code
PDC	Pacific Disaster Center
PGD	Permanent Ground Deformation
PGV	Peak Ground Velocity
RCMP	Residential Construction Mitigation Program
REL	Religion/Non-Profit
RES	Residential
RM	Reinforced Masonry
S	Steel
SBT	Specific Building Type
sec	Second
SECB	Steel, Engineered Commercial Building

Acronym/Abbreviation	Definition
SERB	Steel, Engineered Residential Building
SFHA	Special Flood Hazard Areas
SFR	Single-family Residential
SIC	Standard Industrial Classification
SLTT	State, Local, Tribal, and Territorial
SLUA	Special Land Use Area
SP	Service Pack
SPM	Single-Ply Membrane
SPM	School Planning & Management Magazine
SPMB	Steel, Pre-Engineered Metal Building
SR	Service Release
TFID	Topological Face Identifier
TIGER	Topologically Integrated Geographic Encoding and Referencing
TS	Tsunami
UBC	Uniform Building Code
UDF	User-Defined Facilities
URM	Unreinforced Masonry
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
VHAMF	Veteran’s Health Administration Medical Facilities
W	Wood
WBC	Wind Building Characteristic
WBD	Watershed Boundary Dataset
WMUH	Wood, Multi-Unit Housing
WSF	Wood, Single-family
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant

Section 1. Introduction to the FEMA Hazus Loss Estimation Methodology

1.1 Background

The Hazus Loss Estimation Methodology provides state, local, tribal, and territorial (SLTT) officials with a decision support software for estimating potential losses from four natural hazards: floods (FL), hurricanes (HU), earthquakes (EQ), and tsunamis (TS). This loss estimation capability enables users to anticipate the consequences of natural hazard events and develop plans and strategies for reducing risk. The Geographic Information Systems (GIS)-based software can be applied to study geographic areas of varying scale with diverse population characteristics and can be implemented by users with a wide range of technical and subject matter expertise.

This Methodology has been developed, enhanced, and maintained by the Federal Emergency Management Agency (FEMA) to provide a tool for developing natural hazard loss estimates for use in:

- Anticipating the possible nature and scope of the emergency response needed to cope with disasters.
- Developing plans for recovery and reconstruction following a disaster.
- Mitigating the possible consequences of natural hazards.

The use of this standardized Methodology provides nationally comparable estimates that allow the federal government to plan natural hazard responses and guide the allocation of resources to stimulate risk mitigation efforts.

This *Hazus Inventory Technical Manual* documents the background information used to establish the baseline datasets provided within the Hazus software. The focus of this manual is the common inventory datasets used by all four individual natural hazard models to provide a single source document that avoids repeating information within the hazard-specific Technical Manuals. Together, these technical documents provide a comprehensive overview of this nationally applicable loss estimation methodology.

In addition to this *Hazus Inventory Technical Manual* and the four hazard-specific Technical Manuals, there are separate Hazus User Guidance documents for each of the four hazards and the Hazus Comprehensive Data Management System (CDMS) tool. Those documents outline the background and instructions for developing a Study Region and defining a scenario to complete a hazard-specific loss estimation study using Hazus. They also provide information on how to modify inventory and improve hazard data and analysis parameters for advanced applications, and how to calculate and interpret loss results.

1.2 Hazus Uses and Applications

Hazus can be used by various users with a wide range of needs for information. An SLTT government official may be interested in the costs and benefits of specific mitigation strategies and may want to know the expected losses if mitigation strategies have (or have not) been applied. Emergency response teams may use the results of a loss analysis in planning and performing emergency response exercises. In particular, they might be interested in the operating capacity of emergency facilities such as fire stations, emergency operations centers, and police stations. Emergency planners may want estimates of temporary shelter requirements for different disaster events. Federal and state government officials may require an estimate of economic losses (both short-term and long-term) in order to direct resources to affected communities after an event. Insurance companies may be interested in the estimated monetary losses, so they can assess asset vulnerability.

Natural hazard loss estimation analyses have a variety of uses for various departments, agencies, and community officials. As users become familiar with the loss estimation methodology, they can determine which Hazus Methodology is the most suitable for their needs, and how to appropriately interpret the results of the analysis.

1.3 Assumed User Expertise

Users can be divided into two groups: those who perform the analysis and those who use the analysis results. For some analyses, these two groups occasionally consist of the same people, but generally this will not be the case. However, the more interaction that occurs between these two groups, the better the analysis will be. End users of the loss estimation analysis need to be involved from the beginning to make results more usable.

Any risk modeling effort can be complex and would benefit from input of an interdisciplinary group of experts. A loss analysis could be performed by a representative team consisting of the following:

- Geologists
- Geotechnical engineers
- Structural engineers
- Architects
- Economists
- Meteorologists
- Wind engineers
- Civil engineers
- Hydrologists
- Social scientists
- Emergency planners
- GIS specialists
- Policy makers

The individuals needed to perform the analysis can provide valuable insight into the risk assessment process. For example, with the direct integration of probabilistic and deterministic earthquake ground motion data from the U.S. Geological Survey (USGS) into Hazus, defining earthquake hazard scenarios using authoritative data has become much easier. In addition to subject matter expert involvement, at least one GIS specialist should participate on the team.

If an SLTT agency is performing the analysis, some of the expertise may be found in-house. Experts are generally found in several departments: building permitting, public works, planning, public health, engineering, information technologies, finance, historical preservation, natural resources, and land records. Although internal expertise may be readily available, the importance of external participation of individuals from academic institutions, citizen organizations, and private industry cannot be underestimated.

1.4 When to Seek Help

The results of a loss estimation analysis should be interpreted with caution because baseline values have a great deal of uncertainty. Baseline inventory datasets are the datasets that are provided with Hazus. If the loss estimation team does not include individuals with expertise in the areas described above, it is advisable to retain objective reviewers with subject matter expertise to evaluate and comment on map and tabular data outputs.

If the user intends to modify the baseline inventory data or default parameters, assistance from a subject matter expert would benefit the project. For example, if the user wishes to change baseline percentages of specific building types for the region, collaborating with a structural engineer with knowledge of regional design and construction practices will be helpful. Similarly, if damage-motion relationships (fragility curves) need editing, input from a structural engineer will be required.

1.5 Technical Support

Technical Support contact information is provided in the Hazus application at **Help|Obtaining Technical Support**. Technical assistance is available via the Hazus Help Desk by email at FEMA-Hazus-support@fema.dhs.gov (preferred) or by phone at 1-877-FEMA-MAP (1-877-336-2627). The FEMA Hazus website also provides answers to frequently asked questions, and information on software updates, training opportunities, and upcoming webinars.

FEMA-provided resources also include the Hazus Virtual Training Library, a series of short videos arranged into playlists that cover various Hazus topics, from an introduction to Hazus methodologies, to targeted tutorials on running Hazus analyses, to best practices when sharing results with decision makers. This easily accessible learning material provides quick topic refreshers, free troubleshooting resources, and engaging guides to further Hazus exploration.

The application's **Help** menu references the help files for ArcGIS. Since Hazus was built as an extension to ArcGIS functionality, knowing how to use ArcGIS and the ArcGIS Help Desk will help Hazus users.

Technical support on any of the four hazards is available at the contacts shown via **Help|Obtaining Technical Support.**

1.6 Uncertainties in Loss Estimates

Although the Hazus software offers users the opportunity to prepare comprehensive loss estimates, it should be recognized that uncertainties are inherent in any estimation methodology, even with state-of-the-art techniques. Any region or city studied will have an enormous variety of buildings and facilities of different sizes, shapes, and structural systems built over a range of years under varying design codes. A variety of components contribute to transportation and utility system damage estimations in certain hazard models.

There are also insufficient comprehensive data from past events or laboratory experiments to determine precise estimates of damage based on different measures of hazard severity, such as known ground motions, flood depths, or wind speeds. To deal with this complexity and lack of data, buildings and components of systems are grouped into categories based on key characteristics. The relationships between measures of hazard severity and average degree of damage with associated losses for each building category are based on current data and available theories.

The results of a natural hazard loss analysis should not be looked upon as a prediction. Instead, they are only an estimate, as uncertainty inherent to the model will be influenced by quality of inventory data and the hazard parameters.

1.7 Hazus Versions and Inventory Status

Table 1-1 below lists each of the Hazus versions and any major changes to baseline inventory data with each release.

Table 1-1 Hazus Versions and Inventory Data[1]

Hazus Version	Release Date	Hazards	Inventory Summary	Replacement Value Model Year
HAZUS97	1997	EQ	1990 Census data, Earthquake added using Census tracts	1994
HAZUS99	Dec. 1999	EQ	1990 Census data	1994
HAZUS99 SR1	2001	EQ	1990 Census data	1994
HAZUS99 SR2	Mar. 2002	EQ, FL	1990 Census data, Flood added using Census blocks	1994
HAZUS-MH 1.0	Jan. 2004	EQ, FL, HU	2000 Census data, Hurricane added using Census tracts	2002
HAZUS-MH MR1	Jan. 2005	EQ, FL, HU	2000 Census data	2002
HAZUS-MH MR2	May 2006	EQ, FL, HU	2000 Census data	2005
HAZUS-MH MR3	July 2007	EQ, FL, HU	2000 Census data, CDMS added	2006
HAZUS-MH MR4	Aug. 2009	EQ, FL, HU	2000 Census data	2006
HAZUS-MH MR5	Dec. 2010	EQ, FL, HU	2000 Census data	2006
Hazus-MH 2.0	Jun. 2011	EQ, FL, HU	2000 Census data, storm surge added (with Hurricane using Census block for analysis)	2006
Hazus-MH 2.1	Feb. 2012	EQ, FL, HU	2000 Census data	2006

Hazus Version	Release Date	Hazards	Inventory Summary	Replacement Value Model Year
Hazus 2.2	Jan. 2015	EQ, FL, HU	2010 Census data	2014
Hazus 2.2 SP1	May 2015	EQ, FL, HU	2010 Census data, optional dasymetric for flood	2014
Hazus 3.0	Nov. 2015	EQ, FL, HU	2010 Census data, dasymetric as default for flood	2014
Hazus 3.1	Apr. 2016	EQ, FL, HU	2010 Census data	2014
Hazus 3.2	Oct. 2016	EQ, FL, HU	2010 Census data	2014
Hazus 4.0	Mar. 2017	EQ, FL, HU, TS	2010 Census data, Tsunami added using National Structure Inventory (NSI) data (with new data in territories)	2014[2]
Hazus 4.2	Jan. 2018	EQ, FL, HU, TS	2010 Census data	2014[2]
Hazus 4.2 SP1	May 2018	EQ, FL, HU, TS	2010 Census data	2018[2]
Hazus 4.2 SP2	Feb. 2019	EQ, FL, HU, TS	2010 Census data	2018[2]
Hazus 4.2 SP3	May 2019	EQ, FL, HU, TS	2010 Census data, update of Essential Facilities with Homeland Infrastructure Foundation-Level Data (HIFLD) data	2018[2]
Hazus 4.2 SP3 Tools and Data	Dec. 2019	EQ, FL, HU, TS	2010 Census data; updated PR and VI data to work with EQ, FL, TS (FEMA, 2019); update of Essential Facilities and some Transportation and Utility Facility data with HIFLD data	2018[2]
Hazus 5.0	Apr. 2021	EQ, FL, HU, TS	2010 Census data, Hurricane modeling capabilities and coastal flood modeling added to PR and VI (FEMA, 2021a), added metadata for all previous 2019 HIFLD updates	2018[2]
Hazus 5.1	Oct. 2021	EQ, FL, HU, TS	2010 Census data, Essential Facilities and some Transportation and Utility Facility data with HIFLD data	2018[2]
Hazus 6.0	Nov. 2022	EQ, FL, HU, TS	2020 Census data, NSI 2022, dasymetric geometries, update of Essential Facilities and some Transportation and Utility Facilities with HIFLD Open data	2022
Hazus 6.1	Nov. 2023	EQ	2020 Census data, NSI 2022, dasymetric geometries, update of Earthquake Mapping schemes replacing statewide defaults with tract level schemes	2022

[1]EQ=Earthquake, FL=Flood, HU=Hurricane, TS=Tsunami, SR=Service Release, MR=Maintenance Release, SP=Service Pack.

[2]Prior to Hazus 6.0, NSI Data for Guam, American Samoa, and Northern Mariana Islands used the 2016 replacement value model.

Section 2. Introduction to Inventory Data

This brief overview of the Hazus Inventory Data is intended to provide general background on natural hazard modeling and how inventory data has been developed in the Hazus program.

The Hazus Methodologies will generate an estimate of the consequences to a city or region from a natural hazard scenario or from a probabilistic hazard. The resulting “loss estimate” will generally describe the scale and extent of damage and disruption that may result from a potential event. The following information can be obtained:

- *Quantitative estimates of losses* in terms of direct costs for repair and replacement of damaged buildings and system components, direct costs associated with loss of function (e.g., loss of business revenue, relocation costs), casualties, household displacements, and quantity of debris.

- *Functionality losses* in terms of loss of function and restoration times for critical facilities such as hospitals, components of transportation and utility systems, and simplified analyses of loss of system function for electrical distribution and potable water systems.

- *Extent of induced hazards* in terms of exposed population and building value due to potential fire following an earthquake.

To generate this information, the Hazus Methodology contains baseline inventory data, including:

- Classification systems used in assembling inventory and compiling information on the building stock, the components of transportation and utility systems, and demographic and economic data.

- Standard calculations for estimating type and extent of damage, and for summarizing losses.

- National and regional databases containing information for use as baseline (built-in) data useable in the calculation of losses if there is an absence of user-supplied data.

These systems, methods, and data have been combined in a user-friendly GIS software for this loss estimation application.

The Hazus software uses GIS technologies for performing analyses with inventory data and displaying losses and consequences on applicable tables and maps. The Methodology permits estimates to be made at several levels of complexity, based on the level of inventory entered for the analysis (i.e., baseline data versus locally enhanced data). The more concise and complete the inventory information, the more accurate the results.

The Methodology to conduct a Hazus analysis incorporates inventory collection and hazard identification into the natural hazards impact assessment. For example, the steps used in the Earthquake Model are as follows:

- *Select the area to be studied.* The Hazus Study Region (the region of interest) is created based on Census tract, county, or state level aggregation of data. The area generally includes a city, county, or group of municipalities. It is generally desirable to select an area that is under the jurisdiction of an existing regional planning group.

- *Specify the earthquake hazard scenario.* In developing the scenario earthquake, consideration should be given to credible earthquake sources and potential fault locations using the USGS and Hazus datasets, or subject matter experts.
- *Provide information on local soil and geological conditions, if available.* Soil characteristics include site classification according to the National Earthquake Hazards Reduction Program (NEHRP) and susceptibility to landslides and liquefaction. Note that soil characteristics are not required when using a USGS ShakeMap.
- *Integrate local inventory data.* Include essential facilities, systems, General Building Stock (GBS), or user-defined facilities.
- *Use the formulas embedded in Hazus*. Compute probability distributions for damage to different classes of buildings, facilities, and system components. Then, estimate the loss-of-function.
- *Compute estimates of direct economic loss, casualties, and shelter needs* using the damage and functionality information.
- *Estimate fire risks following earthquake impacts*, such as the number of ignitions and extent of fire spread.
- *Estimate the amount and type of debris.*

The user plays a major role in selecting the scope and nature of the output of a loss estimation analysis. A variety of maps can be generated for visualizing the extent of the losses. Generated reports provide numerical results that may be examined at the level of the Census block or tract or aggregated by county or region.

2.1 Inventory Data Overview

An important requirement for estimating losses is the identification and valuation of the building stock, systems, and population exposed to a hazard, i.e., an inventory. Consequently, Hazus includes a comprehensive inventory for use in estimating losses. This inventory serves as the baseline when the users of the model do not have better data available. The inventory data represent the General Building Stock for the continental United States, Alaska, Hawaii and the U.S. Territories and also includes demographic information. Additionally, the model contains national data for essential facilities and systems. This inventory is used to estimate damage and the direct economic losses for the GBS or the associated impact to functionality for essential facilities, transportation systems and utility systems.

There are differences in the terminology used to distinguish between types or categories of structures. The term “structure” refers to all constructions, such as a building, bridge, water tank, shed, carport, or other man-made thing that is at least semi-permanent. A building is a structure with a roof and walls that is intended for use by people and/or inventory and contents, such as a house, school, office, or commercial storefront. A facility corresponds to a particular place, generally a building, with an intended purpose, such as a school, hospital, electric power station, or water treatment facility. Some facilities are defined as “essential facilities” meaning the facility is critical to maintaining services and functions vital to a community, especially during disaster events. The buildings, essential facilities, and transportation and utility systems considered by the Hazus Methodology are as follows:

- *General Building Stock:* The key GBS databases in Hazus include building area (calculated as square footage) by occupancy and building type, building count by occupancy and building type, building and content valuation by occupancy and building type, and general occupancy mapping. Most of the commercial, industrial, and residential buildings in a region are not considered individually when calculating losses. Buildings within Census subdivisions (either Census tract or block, depending on the hazard) are aggregated and categorized. Building information derived from NSI data, USA Structures and other best-available public sources are used to form groups of specific building types for each hazard and 33 occupancy classes. Degree of damage is computed for each grouped combination of specific building type and occupancy class.

- *Essential and high potential loss facilities*: Essential facilities are those facilities vital to emergency response and recovery following a disaster. They can include medical care facilities, police and fire stations, emergency operations centers (EOC), and schools. For this class of structures, damage and loss-of-function are evaluated on a building-by-building basis. There may be significant uncertainties in each estimate and the losses are intended to help prioritize mitigation strategies including future studies. Essential facilities may also include high potential loss facilities. These facilities include dams and levees, nuclear power plants, and military installations; however, with the exception of military facility data in Puerto Rico and the U.S. Virgin Islands, these kinds of high potential loss facility data are not included in the baseline Hazus inventories.

- *Transportation systems*: Transportation systems, including highways, railways, light rail, bus systems, ports, ferry systems, and airports, are classified into components such as bridges, stretches of roadway or track, terminals, and port warehouses. Dependent on the hazard, probabilities of damage and losses are computed for each component of the system but total system performance is not evaluated, and cascading impacts from one system to another are not analyzed.

- *Utility systems*: Utility systems, including potable water, electric power, wastewater, communications, and liquid fuels (oil and gas), are treated in a manner like transportation systems. Dependent on the hazard, probabilities of damage and losses are computed for each component of the system but total system performance is not evaluated, and cascading impacts from one system to another are not analyzed.

2.2 Level of Analysis

Hazus is designed to support two general types of analysis, Basic and Advanced, split into three levels of data updates (Levels 1, 2, and 3). Figure 2-1 provides a graphic representation of the various levels of analysis.

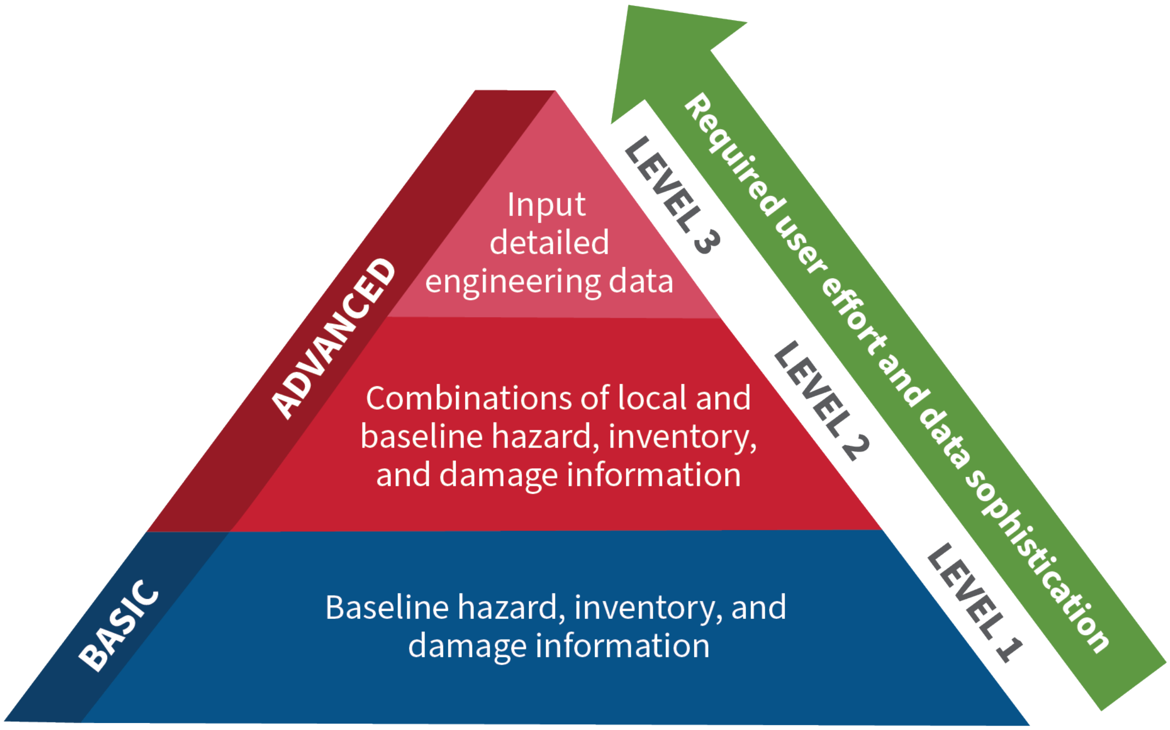


Figure 2-1 Level of Hazus Analysis

2.2.1 Analysis Based on Baseline Information

The basic level of analysis uses only the baseline databases built into the Hazus software and Methodology for building area and value, population characteristics, costs of building repair, and certain basic economic data. This level of analysis is commonly referred to as a Level 1 analysis. In a basic analysis (Level 1), hazard data is uniformly applied or generated from minimal input data and applied to the baseline inventory data with little to no user modification. Direct economic and social losses associated with the General Building Stock and essential facilities are computed. Baseline data for transportation and utility systems are included; thus, these systems are considered in the basic level of analysis. There is a significant level of uncertainty pertaining to the estimates and this basic analysis is only available in certain hazard models. However, with recent Hazus inventory updates, significant improvements to baseline inventories and application of hazard data continue to enhance the quality of the baseline loss estimates.

Other than defining the Study Region, selecting hazard information, and making decisions concerning the extent and format of the output, an analysis based on baseline data requires minimal effort from the user. As indicated, the estimates involve large uncertainties when inventories are limited to the baseline data. This level of analysis is suitable primarily for preliminary evaluations and comparing losses across jurisdictions or regions or Census blocks. A basic Level 1 analysis could be used for comparisons and preliminary evaluations to assist in identifying potential mitigation actions within a community, which could be useful if prioritizing mitigation strategies for mitigation planning based on the potential to reduce losses and risk.

2.2.2 Analysis with User-Supplied Inventory

Results from an analysis using only baseline inventory can be improved upon greatly with at least a minimum amount of locally developed input. Improved results are highly dependent on the quality and quantity of improved inventory data. The significance of the improved results also relies on the user's analysis priorities. This level of advanced analysis is commonly referred to as a Level 2 or Level 3 analysis. The following inventory improvements impact the accuracy of Level 2 and Level 3 advanced analysis results:

- Use of locally available data or estimates of the square footage of buildings in different occupancy classes.
- Use of local expertise to modify (primarily by professional judgment) the databases that determine the percentages of specific building types associated with different occupancy classes.
- Preparation of a detailed inventory of all essential facilities.
- Collection of detailed inventory and cost data to improve evaluation of losses and lack of function in various transportation and utility systems.
- Use of locally available data concerning construction costs or other economic parameters.
- Compilation of information concerning high potential loss facilities.

Section 3. General Building Stock: Spatial Data

Each of the four hazard models in Hazus uses a different baseline spatial approach to apply General Building Stock data.

- Earthquake and hurricane modeling are typically performed at the Census tract geometry.
- Flood modeling is performed at the Census block with geometries enhanced to represent developed areas to better reflect the geographic scale sensitivity of flood hazards.
- Tsunami modeling is performed using NSI 2022 point data distributed in the Census blocks representation.

The development of Hazus General Building Stock data has changed over time as more hazards were modeled and geographic coverage expanded to the territories.

- For the Earthquake Model, Hazus supports Study Regions and analysis in all 50 states, American Samoa, District of Columbia, Guam, Northern Mariana Islands, Puerto Rico and the U.S. Virgin Islands.
- For the Flood Model, Hazus supports Study Regions and analysis in all 50 states, District of Columbia, Puerto Rico and the U.S. Virgin Islands. Hazus Level 1 Riverine Flood analysis limitations exist with Puerto Rico, U.S. Virgin Islands, Alaska, and Hawaii except Oahu due to lack of regional regression equations.
- For the Hurricane Model, Hazus supports Study Regions and analysis in Hawaii, Puerto Rico, U.S. Virgin Islands, and the 20 Atlantic and Gulf of Mexico states that fall within the American Society of Civil Engineers (ASCE) High Wind Zone (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, West Virginia, District of Columbia, Maryland, Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Texas).
- For the Tsunami Model, Hazus supports Study Regions and analysis in five very high-risk states on the Pacific coast (Hawaii, Alaska, Washington, Oregon, California) and five high risk territories (Puerto Rico, U.S. Virgin Islands, Guam, American Samoa and Northern Mariana Islands).

This section summarizes Hazus inventory information based on the different types of GBS spatial data, all of which will be described in greater detail later in this section:

- *Census Boundary Data:* These data relate to Hazus's use of slightly modified (clipped for water features) baseline U.S. Census boundaries at the tract and block subdivision levels with tract centroids adjusted based on developed areas.
- *Dasymetric Data:* These block-level data, also primarily based on the U.S. Census boundaries, have been modified based on land cover and building footprint data to include those areas where structures are to be found. Dasymetric data serve as the analysis basis for the Hazus Flood Model.

- *Homogeneous Boundaries:* Homogeneous area boundaries are based on the original (clipped) U.S. Census block and tract features and are not limited to the developed areas reflected in the dasymetric data. They are referred to as “homogeneous” based on the assumption that the underlying Census data is uniformly distributed throughout the entirety of the Census block or tract. The homogeneous boundary datasets are used for Study Region aggregation for all hazards.
- *Community Boundary Data:* Community boundary data, utilized primarily by the Hazus Flood Model, include boundaries for local jurisdictions/communities, tribal areas and Special Land Use Areas (SLUAs).
- *Approximate Site-Level Data:* These site-level data approximated by points were developed using data from the NSI (USACE, 2022) for the U.S. states and FEMA Natural Hazards Risk Assessment Program (NHRAP) for the U.S. territories takes a different approach to identifying structure locations by distributing structure coordinates (points) within the developed areas of Census blocks. Table 1-1, shown earlier in this document, describes Hazus versions and includes information on when each of these spatial data types was first introduced in Hazus.

3.1 Census Boundary Data

Census blocks, the smallest geographic area for which the Bureau of the Census collects and tabulates decennial Census data, were formed by streets, roads, railroads, streams and other bodies of water, other visible physical and cultural features, and the legal boundaries shown on Census Bureau maps. Conceptually, a Census block can be thought of as a unit with roughly the population of a city block. However, there is no official minimum population for a Census block (almost half have zero population), and the original 1990 minimum size of 30,000 square feet can be overwritten, when it makes sense, by bounding features. There is also no maximum size for a Census block, so in low population rural areas Census blocks can be several to hundreds of square miles. In Hazus, the dasymetric blocks include only the developed areas and average just 0.03 square kilometers with a maximum of 10.6 square kilometers and a sum of the entire developed area for all U.S. (inclusive of the territories and DC) regions combined of about 225,000 square kilometers. To implement Census blocks (and other Census boundaries such as tracts) within a database environment, the Census Bureau made use of Geographic Identifiers (GEOIDs) to establish a unique naming convention to apply to different geographic areas. In Hazus, the most common GEOIDs used are Census blocks (15-digit code), Census tracts (11-digit code), and counties (5-digit code). More information on Census boundaries and the use of GEOIDs can be found at Census Bureau (2018) as listed in Section 11 of this document.

The baseline General Building Stock spatial data for the Earthquake and Hurricane Models use the 2020 Census tracts. The 2020 Census blocks are the original baseline General Building Stock spatial data for flood, and for when a combined storm surge analysis is conducted using both hurricane and flood. Tract and block data are clipped using the water features from the U.S. Census Bureau Topologically Integrated Geographic Encoding and Referencing (TIGER) Areal Hydrography Geodatabase and updated using the developed areas from the dasymetric processing.

The 2020 Census uses about 8 million Census blocks across the entire United States and its territories. This is about a 27% decrease from the number of blocks used in the 2010 Census. Almost every state and territory saw a substantial reduction in total Census blocks, with only Rhode Island gaining in total Census blocks (+2%). This redistricting and consolidation of blocks required a complete regeneration of the Census block boundaries. In addition to incorporating the 2020 Census boundaries, the process refined representation of coastal boundaries and removed all water body blocks. As will be described in the next section, the baseline Census block boundary data has been further clipped or removed based on building data and land use, known as dasymetric data, for use in flood and storm surge analyses and distribution of the building points used in Tsunami analysis. Following this process some 6.8 million Census blocks are used in Hazus.

There are some data maintenance considerations Hazus users should keep in mind related to Census boundary data:

- *Boundary changes.* Many boundaries, especially at the Census block level, change over time. For areas with high growth, each decadal Census might alter existing tracts and blocks, both adding new features and changing spatial boundaries. There is not a simple 1-to-1 relationship between any two sets of Census data from different decennial Census. Even county-level information may change over time with new counties being created or old counties being merged and renamed. Also, modern surveying methods can correct past errors and alter county and sometimes state boundary data over time.
- *Census updates.* While new Census boundary data are often available prior to each Census, the associated detailed tabular data for population counts that is used by Hazus typically is not released until years after each Census. Therefore, Hazus Census-related data may not be updated until the data becomes available following each Census.

Some elements in the GBS baseline database are established from Census Bureau sources that are at a courser resolution than individual state data. Table 3-1 displays the lists of states within Census regions and divisions. Territories are assigned to a Census Region but are not assigned to Census divisions.

Table 3-1 Census Regions and Divisions

Census Region	Census Division	States/Territories
Northeast	New England	CT, MA, ME, NH, RI, VT
Northeast	Middle Atlantic	NJ, NY, PA
Midwest	East North Central	IL, IN, MI, OH, WI
Midwest	West North Central	IA, KS, MN, MO, ND, NE, SD
South	South Atlantic	DC, DE, FL, GA, MD, NC, PR, SC, VA, VI, WV
South	East South Central	AL, KY, MS, TN
South	West South Central	AR, LA, OK, TX
West	Mountain	AZ, CO, ID, MT, NM, NV, UT, WY
West	Pacific	AK, AS, CA, GU, HI, MP, OR, WA

3.2 Dasymetric Data

Several types of input data sources were used to build the national dasymetric dataset, including geographic boundaries supplied by the U.S. Census Bureau, a land cover classification raster, and multiple sources of national building footprint spatial datasets. This data, detailed in Table 3-2, was used to more accurately define developed area in the final dasymetric output.

Table 3-2 Dasymetric Input Data

Hazus 6.0 Dataset Name	Hazus 6.0 Dataset Date	Hazus 6.0 Dataset Source	Description of Hazus 6.0 Dataset	Geographic Coverage
Microsoft Bing Building Footprints Dataset	2018	Microsoft	Microsoft - open building footprints for the U.S., actual imagery dates vary.	Continental United Stated (CONUS)
National Land Cover Database (NLCD)	2019	Multi-Resolution Land Characteristics Consortium (MRLC)	Nationwide data on land cover at a 30 meter resolution with a 16-class legend based on a modified Anderson Level II classification system.	CONUS
NSI 2022	June 2022	U.S. Army Corps of Engineers (USACE)	Point-based structure inventories. Developed from Lightbox Parcel, National Geospatial-Intelligence Agency (NGA) lidar, USA Structures and Bing footprints.	AK, HI, CONUS except DC
U.S. Territories Building Footprint Dataset	2018	FEMA NHRAP	Lidar-based polygon building footprints. AS lidar sourced from NOAA (National Atmospheric and Oceanic Association) (2012). GU lidar sourced from USGS (2012-13) and parcel data from 2007. MP lidar sourced from USACE (2007) and parcel data from 2006.	AS, GU, MP
U.S. Territories Building Point Dataset	2018	FEMA NHRAP	Additional lidar-based point file.	GU
PR Building Footprint Dataset	2015	FEMA NHRAP	2015 USGS lidar-based building footprints, reprocessed in 2020 to remove slivers and duplicates.	PR

Hazus 6.0 Dataset Name	Hazus 6.0 Dataset Date	Hazus 6.0 Dataset Source	Description of Hazus 6.0 Dataset	Geographic Coverage
VI Building Footprint Dataset	2013	FEMA NHRAP	2013 USGS lidar-based building footprints, reprocessed in 2020 to remove slivers and duplicates.	VI
USA Structures Dataset	2021	Department of Homeland Security, Federal Insurance and Mitigation Administration, FEMA's Response Geospatial Office, Oak Ridge National Lab (ORNL), USGS	Building footprints extracted from aerial imagery ranging in dates, urban areas are supplemented with NGA lidar.	All U.S.
U.S. Census Bureau TIGER Areal Hydrography Geodatabase	2021	U.S. Census Bureau	Geometry and attributes of both perennial and intermittent area hydrography features.	All U.S.
U.S. Census Bureau TIGER Census Blocks Geodatabase	2021	U.S. Census Bureau	A geodatabase that contains all Census blocks for the nation.	All U.S.
U.S. Census Bureau TIGER Census Tract Layer	2021	U.S. Census Bureau	A layer containing all Census tracts for the nation.	All U.S.
U.S. Census Bureau TIGER Coastline National Shapefile	2021	U.S. Census Bureau	A shapefile containing coastline features.	All U.S.
U.S. Census Bureau TIGER County Layer	2021	U.S. Census Bureau	A layer containing all counties for the nation.	All U.S.
U.S. Census Bureau TIGER Faces County Files	2021	U.S. Census Bureau	These topological faces shapefiles contain the attributes of each topological primitive face. Each face has a unique topological face identifier (TFID) value.	All U.S.

To support the development of the national dasymetric dataset, a dedicated PostgreSQL database environment and custom dasymetric processing code was established. Using a relational database with spatial capabilities to process the necessary data in combination with dasymetric business logic code provides several benefits including ease of methodology implementation, better quality control, and repeatability. Figure 3-1 provides an example of new dasymetric Census blocks in Hazus 6.0 compared to the traditional 2020 U.S. Census blocks and world imagery.

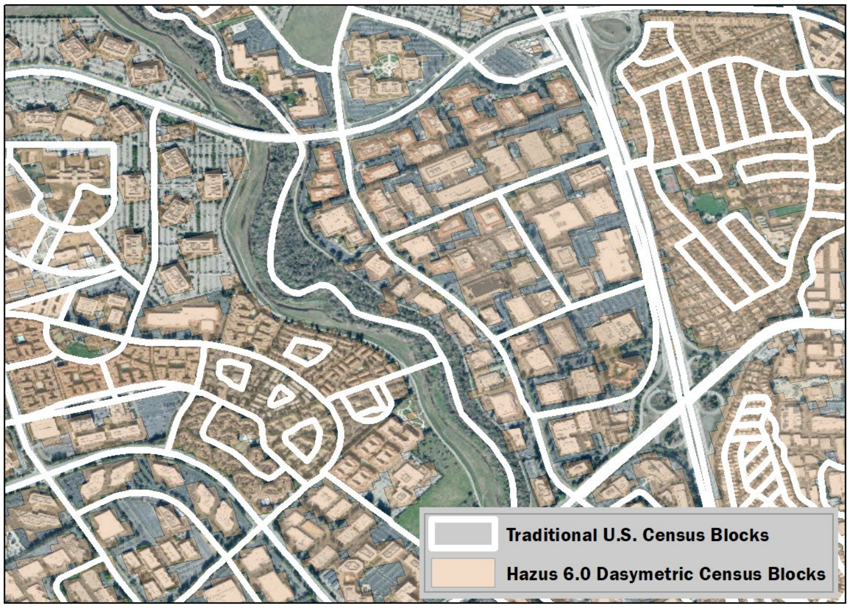


Figure 3-1 Example of New Dasymetric Census Blocks in Hazus 6.0

Census blocks which contain only water were removed from input into the dasymetric processing of the TIGER Census block boundaries. The field “ALAND20” gives the total land area of the Census block. If this field value was zero, no dasymetric geometry was created for the Census block.

The 2019 NLCD raster pixels associated with the remaining Census blocks were identified for each Census block. The intersection of the input USA Structures dataset and the Census blocks were then used to identify NLCD pixels which included developed area based on building presence. If any pixel intersecting the USA Structures footprint had a value of 11 (indicating the land cover classification Open Water), that building was not used to create dasymetric geometry. Otherwise, pixels intersecting the footprint were marked for inclusion in further processing. This same process was then performed using the input Microsoft Bing Building Footprint and Census block intersection. At this point if the Census block had no marked pixels for the USA Structures and Microsoft Bing building footprints, all NSI locations for the Census block were evaluated to determine if they were valid locations. Otherwise, the NSI 2022 dataset was filtered to exclude points with a questionable source (NSI attributes: Source = ‘X’ and Ftprntsrc = ‘Null’). The NSI point was then buffered by a radius extrapolated from the square footage of the building as denoted by the point’s attributes. The resulting polygon was then used in the same way as the other building footprints to include the pixel for processing if the polygon did not intersect an Open Water pixel.

For the U.S. territories (American Samoa, Northern Mariana Islands, Guam, Puerto Rico, and the U.S. Virgin Islands), the datasets identifying input buildings were each spatially intersected with the Census block polygons to establish a building-Census block relationship. These datasets were the USA

Structures dataset, the U.S. Territories Building Footprint dataset, and U.S. Territories Building dataset. The U.S. Virgin Islands did not utilize the USA Structures dataset and only used the U.S. Territories Building dataset. USA Structures and U.S. Territories Building datasets were each spatially intersected with the water bodies in the 2021 TIGER Area Hydrography layer to establish a building-water body relationship. Any building footprint polygons in Puerto Rico specifically that intersected a water body of Master Address File (MAF)/TIGER Feature Class Code (MTFCC) type “Stream/River” were filtered out of the dataset. This filtering was performed due to errors in the building source data where boats or piers may have been identified as buildings. All other territories utilized the same MTFCC filtering applied for the 50 states and the District of Columbia. A set of specific building attribute IDs were filtered out of inputs for American Samoa, Northern Mariana Islands, and the U.S. Virgin Islands, as they were identified as non-building objects such as pools, solar panels, bridges, or tanks. The building footprints used to create the Puerto Rico dasymetric data were missing significant settlements which may lead to inaccurate loss estimates.

Raster grids for each territory were created at a 30 meter resolution to emulate the NLCD 30 meter resolution grid used for the 50 states and the District of Columbia. After water-only Census blocks were removed, the raster pixels associated with the remaining Census blocks were identified. Pixels intersecting the USA Structures building footprints were marked for inclusion in further processing. This same process was then performed using the U.S. Territories Building Footprint dataset, U.S. Territories Building dataset and Census block intersection. For Guam specifically, the U.S. Territories Building Point Dataset identified buildings not captured in the U.S. Territories Building Footprint polygon dataset. After the U.S. Territories Building Point dataset was intersected with the Census block polygons, if the Guam points did not intersect a pixel already identified as USA Structures, then the point was buffered by a radius of 6 meters. The resulting polygon was then used in the same way as the other building footprints to include the pixel for processing.

For the entire national dataset, all marked pixels for a Census block were unioned and then the Census block boundary was used to clip the unioned shape to generate the final product, the Census block dasymetric geometry. The area associated with each Census block dasymetric geometry was calculated in the WGS84 geographic coordinate system (GCS) with the appropriate Universal Transverse Mercator (UTM) zone projection.

For more detailed information on specific processes used to implement this methodology, please contact the Hazus Help Desk to request further documentation (see Section 1.5).

3.2.1 Centroid Calculation

The Census block centroid was determined as the central point of the dasymetric area of the block. If the true centroid, the actual central point of the Census block regardless of Census boundaries, falls outside of the associated native TIGER Census block, the centroid was regenerated to be placed within the associated block boundary. During hurricane modeling efforts, 76 CONUS tract centroids and 17 tract centroids outside of the Continental United States (OCONUS) were updated. These adjustments were needed to support the Hazus wind model requirements that centroids are located inland of the coastline used for wind speed model calculations.

3.3 Homogenous Boundaries

Hazus historically used Census data that was uniformly (homogeneously) distributed throughout a Census block. Unlike dasymetric, homogenous boundaries include undeveloped areas and align with Census boundaries. The homogeneous boundary datasets are used for Study Region aggregation for all hazards and serve as the analysis basis for the Hazus Earthquake Model. The Hurricane Model uses both homogeneous boundaries and dasymetric data. The Flood Model and Tsunami Model use the dasymetric block data.

TIGER 2021 native boundaries (Census block, Census tract and County) were primarily used for the hzBlock_TIGER, hzTract and hzCounty shapes except for modifications made in the vicinity of large lakes and coastal regions. Modified boundary shapes were created by first utilizing the 2021 TIGER Areal Hydrography dataset to identify and remove faces from the 2021 TIGER Faces dataset which intersect lakes larger than 500 square miles in area. Faces whose centroid intersected either the USGS National Boundary polygons (CONUS, Alaska, Hawaii, Puerto Rico, and the U.S. Virgin Islands) or the 2020 TIGER Coastline represented as polygons (American Samoa, Guam, and the Northern Mariana Islands) were also removed. The remaining faces were then aggregated to the Census block-, tract-, and county-levels to produce the modified homogenous block, tract, and county boundaries. Table 3-3 describes the fields and data sources used.

Table 3-3 Geodatabase Field Descriptions - hzCensusBlock and hzCensusBlock_Tiger

Field Name	Data Source	Description
OBJECTID	Hazus Program Generated	The national TIGER 2021 Census block data was loaded into a dedicated PostgreSQL database environment. These data records were ordered by statefp20, countyfp20, tractce20, and blockfce20 and had a unique identifier applied (hazus_object_id). This “internal” Census block-level hazus_object_id is the value that is being displayed in the OBJECTID field.
Shape	Hazus Program Generated	The dasymetric shape generated from business logic contained in the dasymetric area generation tool. Shape is provided in GCS WGS84.
CensusBlock	TIGER 2021 Census Block	The TIGER 2021 Census block geoid20 value; it is a unique identifier.
Tract	TIGER 2021 Census Block	A concatenation of the Census block’s statefp20, countyfp20 and tractce20 values.
BldgSchemesId	Hazus Program Generated	Building scheme unique ID, assigned at the County level. See *Hazus Earthquake Model Technical Manual* (FEMA, 2022a) for more information.
BlockType	Hazus Program Generated	Indicated Coastal, Riverine or Lake block assignments used for flood mapping schemes. See Section 5.6.1 and Section 5.6.3 for more information.

Field Name	Data Source	Description
BlockArea	Hazus Program Generated	The area of the dasymetric block shape was calculated using UTM. To determine the appropriate UTM zone parameters for this calculation, the TIGER 2021 Census block internal point longitude value (intptlon20) was used. Each dasymetric block shape was projected to its appropriate UTM zone and then the area was calculated and stored in square meters using 4 decimal places. The value displayed in the BlockArea field has been converted to square kilometers representing the developed area only.
CenLat	Hazus Program Generated	Coordinate of the centroid latitude; it is in the GCS WGS84.
CenLongit	Hazus Program Generated	Coordinate of the centroid longitude; it is in the GCS WGS84.
PctWithBasemnt[1]	EIA (2009)	Percentage of buildings with an Occupancy code of RES1 that have a basement (see Table 6-8).
Pct1StoryRes1[1]	EIA (2009)	Percentage of buildings with an Occupancy code of RES1 that are 1 Story (see Table 6-9).
Pct2StoryRes1[1]	EIA (2009)	Percentage of buildings with an Occupancy code of RES1 that are 2 Story (see Table 6-9).
Pct3StoryRes1[1]	EIA (2009)	Percentage of buildings with an Occupancy code of RES1 that are 3 Story (see Table 6-9).
PctSplitLvlRes1[1]	EIA (2009)	Percentage of buildings with an Occupancy code of RES1 that are Split Level (see Table 6-9).
Pct1to2StryRes3[1]	EIA (1997)	Percentage of buildings with an Occupancy code of RES3A - RES3F that are 1 to 2 Story buildings. Used in precompiled flood mapping schemes from [flTmpDB].[dbo].[flGBSDistRes].
Pct3to4StryRes3[1]	EIA (1997)	Percentage of buildings with an Occupancy code of RES3A - RES3F that are 3 to 4 Story.
Pct5StryplusRes3[1]	EIA (1997)	Percentage of buildings with an Occupancy code of RES3A - RES3F that are 5 Story or more.

Field Name	Data Source	Description
PctLowRiseOther[1]	EIA (2003)	Percentage of buildings with Occupancy codes other than RES1 or RES3A – RES3F that are low-rise buildings. Used in precompiled flood mapping schemes from [flTmpDB].[dbo].[flGBSDistNonRes].
PctMidRiseOther[1]	EIA (2003)	Percentage of buildings with Occupancy codes other than RES1 or RES3A – RES3F that are mid-rise buildings.
PctHighRiseOther[1]	EIA (2003)	Percentage of buildings with Occupancy codes other than RES1 or RES3A – RES3F that are high-rise buildings.
Pct1CarGarage[1]	EIA (2009)	Percentage of buildings with Occupancy code RES1 with a 1-car garage (see Table 5-5).
Pct2CarGarage[1]	EIA (2009)	Percentage of buildings with Occupancy code RES1with a 2-car garage (see Table 5-5).
Pct3CarGarage[1]	EIA (2009)	Percentage of buildings with Occupancy code RES1with a 3-car garage (see Table 5-5).
PctCarPort[1]	EIA (2009)	Percentage of buildings with Occupancy code RES1with a carport (see Table 5-5).
PctNoGarage[1]	EIA (2009)	Percentage of buildings with Occupancy code RES1with no garage (see Table 5-5).
IncomeRatio	U.S. Census Bureau	The Census block group median income divided by the average median income for the State.
dasymetric_log_id	Hazus Program Generated	A generated identifier that provides traceability to the dasymetric area generation tool settings used to produce each record.

[1]*Values vary by State.*

The hzCensusBlock_TIGER table has the same content as the hzCensusBlock with the following exceptions: shape was provided in GCS WGS84 and the shape was the native TIGER Census block geometry with the exception of modifications made in the vicinity of large lakes and coastal regions. Due to exceeding the 10GB SQL database limit with the new earthquake mapping schemes in California, the hzCensusBlock_TIGER feature class had to be removed in Hazus 6.1.

Centroid was determined for Census tract dasymetric area. If the true centroid fell outside of the associated native TIGER Census tract, the centroid was regenerated to be placed within the associated Census tract boundary. An additional check was performed to verify that the centroid did not fall within a water-only native TIGER Census block. If it did, the centroid was regenerated to be placed within the union-aggregated shape of all native TIGER Census blocks associated with the tract.

Table 3-4 describes the fields and data sources used for hzTract and Table 3-5 describes the fields and data sources used for hzCounty.

Table 3-4 Geodatabase Field Descriptions - hzTract

Field Name	Data Source	Description
OBJECTID	Hazus Program Generated	The national TIGER 2021 Census tract data was loaded into a dedicated PostgreSQL database environment. These data records were ordered by statefp20, countyfp20, and tractce20 and a unique identifier applied (hazus_object_id). This "internal" tract-level hazus_object_id is the value that is displayed in the OBJECTID field.
Shape	Hazus Program Generated	Shape is provided in GCS WGS84. The shape is the native TIGER Census tract geometry with the exception of modifications made in the vicinity of large lakes and coastal regions.
Tract	TIGER 2021 Tract	A concatenation of the Census tract statefp20, countyfp20 and tractce20 values.
CountyFips	TIGER 2021 Tract	A concatenation of the Census tract statefp20 and countyfp20 values.
BldgSchemesId	Hazus Program Generated	The ID that relates to the Building Mapping Schemes used to calculate damages for a specific hazard (see Section 5.4).
Tract6	TIGER 2021 Tract	TIGER 2021 tract tractce20 value.
TractArea	Hazus Program Generated	The calculated area associated with each tract. This value is generated by projecting the geometries into the GCS WGS84 UTM Zone and calculating the areas in square kilometers. These areas represent the entire homogeneous geometries of each tract including both the developed and undeveloped areas.
NumAggrBlocks	Hazus Program Generated	The count of Census blocks that have dasymetric area within this tract.
CenLat	Hazus Program Generated	Coordinate of each centroid latitude in the GCS WGS84.
CenLongit	Hazus Program Generated	Coordinate of each centroid longitude in the GCS WGS84.

Field Name	Data Source	Description
Length	Hazus Program Generated	Value generated by determining a relationship from roads to tract using TIGER roads, edges, faces, and tracts and measuring the length of these roads. The road types included in this analysis are Primary Roads (MTFCC = S1100), Secondary Roads (MTFCC = 1200), and Local Neighborhood Road/Rural Road/City Street (MTFCC = S1400). When a road link borders more than one tract, the length of the edges that make up the road link are equally distributed (50%) between the left and right tract that the link borders. All edges within a tract are summed and then converted from meters to kilometers to produce the hzTract Length value.
dasymetric_log_id	Hazus Program Generated	A generated identifier that provides traceability to the dasymetric area generation tool settings used to produce each record.

Table 3-5 Geodatabase Field Descriptions - hzCounty

Field Name	Data Source	Description
OBJECTID	Hazus Program Generated	The national TIGER 2021 County data was loaded into a dedicated PostgreSQL database environment. These data records were ordered by statefp20 and countyfp20 and had a unique identifier applied (hazus_object_id). This “internal” county-level hazus_object_id is the value that is being displayed in the OBJECTID field.
Shape	Hazus Program Generated	Shape is provided in GCS WGS84. The shape is the native TIGER county geometry with the exception of modifications made in the vicinity of large lakes and coastal regions.
CountyFips	TIGER 2021 County	A concatenation of the county’s statefp20 and countyfp20 values.
CountyFips3	TIGER 2021 County	TIGER 2021 Tract countyfp20 value.
CountyName	TIGER 2021 County	TIGER 2021 County Name value.
State	TIGER 2021 State	TIGER 2021 State stusps value.
StateFips	TIGER 2021 County	TIGER 2021 County statefp20 value.
NumAggrTracts	Hazus Program Generated	The count of Census tracts that have dasymetric area within this county.

3.4 Community Boundary Data

The hzCommunity layer is a composite of three FEMA datasets, as described in Table 3-6.

Table 3-6 hzCommunity Input Data

Hazus 6.0 Dataset Name	Hazus 6.0 Dataset Date	Hazus 6.0 Dataset Source	Description of Hazus 6.0 Dataset	Geographic Coverage	Previous Data Source (Hazus 5.1)
National Flood Insurance Program (NFIP) Map Production Pro (MPP) Jurisdictions v3.0.26	Extracted April 21, 2022	FEMA	Community layer of participating NFIP jurisdictions.	All U.S.	NFIP Community Layer (2014)
NFIP Community Layer v3 - Tribal	2020	FEMA	Community layer of participating NFIP Tribal Governments.	All U.S.	NFIP Community layer of all tribes
NFIP Community Layer v3 - SLUA	2020	FEMA	Community layer of participating NFIP SLUAs.	All U.S.	NFIP Community layer of all SLUAs

It was determined that all communities were to be represented, whether they had a Community Identification Number (CID) or not. CID was used where available and a customized Area_ID was developed for others.

The three layers were merged together with the appropriate attributes for each column listed below in Table 3-7. All communities that did not have a CID were then deleted.

Table 3-7 hzCommunity Attributes by Data Source

Attribute	NFIP MPP Jurisdictions Data Sources	Tribal Data Sources	SLUA Data Sources
Area_ID	CID Column and GEOID. CID is used for participating jurisdictions and custom IDs developed from GEOID was used for others.	CID for participating tribes and custom GEOID for others.	CID for participating SLUAs and custom GEOID for others.
CommunityName	Names were populated from other fields in priority order based on: 1. CIS_COMMUN; 2. CENSUS_COM; 3. COMMUNITY_; 4. alt_name.	cen_namelsad column supplemented with cis_community_name_full column when required.	cs_community_name_full
CommunityType	0	1	2
Block Count	Null	Null	Null

Attribute	NFIP MPP Jurisdictions Data Sources	Tribal Data Sources	SLUA Data Sources
Shape	27,905 total polygon entries	860 total entries	27 total entries

Since each community needs a unique Area_ID, polygons with the same Area_ID values were merged. The community names for these areas sometimes contained slightly different community names. Therefore, during the dissolve, the first name was selected.

Users are able to build flood Study Regions based on all the Census blocks within their entire community boundary. The three different files (Jurisdictions, Tribal, and SLUAs) are merged into one dataset where the Hazus shell allows selection of each based on CommunityType. The resulting dataset was then clipped to the hzCounty layer to reduce the number of islands outside of the areas assessed by Hazus. Table 3-8 describes the input data and data source information for this layer.

Table 3-8 hzCommunity_Block Input Data

Hazus 6.0 Dataset Name	Hazus 6.0 Dataset Date	Hazus 6.0 Dataset Source	Description of Hazus 6.0 Dataset	Geographic Coverage	Previous Data Source (Hazus 5.1)
Hazus Dasymetric Census Blocks	2022	Hazus Program Generated	Dasymetric Census block feature class (see Section 3.2).	All U.S.	2010 U.S. Census blocks, 2011 NLCD Dataset
NFIP MPP Jurisdictions v3.0.26	Extracted April 21, 2022	FEMA	Community layer of participating NFIP jurisdictions.	All U.S.	NFIP Community Layer (2014)
NFIP Community Layer v3 - Tribal	2020	FEMA	Community layer of participating NFIP Tribal Governments.	All U.S.	NFIP Community layer
NFIP Community Layer v3 - SLUA	2020	FEMA	Community layer of participating NFIP SLUAs.	All U.S.	NFIP Community layer

The Area_ID field values were calculated for each community in the Jurisdictions, Tribal Areas, and SLUA communities using the source data as outlined in Table 3-9. Each of the three jurisdiction layers (Jurisdictions, Tribal, and SLUA), were treated separately, determining for each Census block which community occupied the largest percentage of space within the Census block. This percentage was then listed within the Ratio attribute. Once all three community layers were finished they were merged.

Table 3-9 hzCommunity Layer Fields by Data Source

Attribute	NFIP MPP Jurisdictions Data Sources	Tribal Data Sources	SLUA Data Sources
Area_ID	CID is used for participating jurisdictions and custom IDs developed from GEOID was used for others.	CID is used for participating jurisdictions and custom IDs developed from GEOID was used for others.	CID is used for participating jurisdictions and custom IDs developed from GEOID was used for others.
CensusBlock	The Census block number from the Hazus Dasymetric Census blocks.	The Census block number from the Hazus Dasymetric Census blocks.	The Census block number from the Hazus Dasymetric Census blocks.
Ratio	Based on the Area_ID with the maximum percentage.	Based on the Area_ID with the maximum percentage.	Based on the Area_ID with the maximum percentage.

The hzCommunity_State layer provides the list of all communities in each state and is derived from the hzCommunity_Block file, which was an aggregate of the Jurisdiction data from the NFIP MPP v3.0.26 data and the Tribal and SLUA communities' data from the NFIP Community Layer v3. Table 3-10 describes the input data and data source information for this layer.

Table 3-10 hzCommunity_State Input Data

Hazus 6.0 Dataset Name	Hazus 6.0 Dataset Date	Hazus 6.0 Dataset Source	Description of Hazus 6.0 Dataset	Geographic Coverage	Previous Data Source (Hazus 5.1)
hzCommunity_Block	2022	Hazus Program Generated	Hazus Community Boundary layer in Census blocks (see Table 3-8).	All U.S.	NFIP Community Information System (CIS) data
NFIP MPP Jurisdictions v3.0.26	Extracted April 21, 2022	FEMA	Community layer of participating NFIP jurisdictions.	All U.S.	NFIP Community Layer (2014)
NFIP Community Layer v3 - Tribal	2020	FEMA	Community layer of participating NFIP Tribal Governments.	All U.S.	NFIP Community layer
NFIP Community Layer v3 - SLUA	2020	FEMA	Community layer of participating NFIP SLUAs.	All U.S.	NFIP Community layer

For each Census block, the community covering the majority of the Census block's geographic area was used to populate the Area_ID field with the CID. The CID was then used to populate the hzCommunity_State layer by dissolving all of the entries by the Area_ID field, reducing each community to one entry. Once this dissolution was complete, a StateFips field was added to the resulting file and populated with the left two characters of the Area_ID field.

Table 3-11 summarizes the input data and data source information for the hzWatershed, syWatershed and syWatershed_Block layers.

Table 3-11 hzWatershed, syWatershed and syWatershed_Block Input Data

Hazus 6.0 Dataset Name	Hazus 6.0 Dataset Date	Hazus 6.0 Dataset Source	Description of Hazus 6.0 Dataset	Geographic Coverage	Previous Data Source (Hazus 5.1)
Hazus Dasymetric Census Blocks	2022	Hazus Program Generated	Dasymetric Census block feature class (see Section 3.2).	All U.S.	2010 U.S. Census blocks, 2011 NLCD Dataset
USGS National Watershed Boundary Dataset in FileGDB 10.1 format	May 2022	USGS	The Watershed Boundary Dataset (WBD) is a comprehensive aggregated collection of hydrologic unit data consistent with the national criteria for delineation and resolution. It defines the areal extent of surface water drainage to a point.	All U.S.	USGS, CONUS only

The hzWatershed layer was created using the latest eight-digit hydrologic unit code (HUC-8) watersheds from the USGS National Watershed Boundary Dataset, using the fields described in Table 3-12.

Table 3-12 hzWatershed Fields by Data Source

Field Name	Data Source	Description
Shape	Hazus Program Generated	Shape is provided in GCS WGS84.
HUC	USGS	Watershed HUC-8 value.
NAME	USGS	Watershed name value.

The syWatershed layer was created using the updated geometries in hzWaterShed and the updated table containing the new Block Counts, which are based on the 2020 Census blocks in syWaterShed_Block. The syWatershed field was comprised of the fields described in Table 3-13.

Table 3-13 syWaterShed Fields by Data Source

Field Name	Data Source	Description
HUC	USGS	Watershed HUC-8 value.
WaterShedName	USGS	Watershed name value.
BlockCount	Hazus Program Generated	The count of the native TIGER Census block geometries modified to remove the shapes of large lakes and coastal regions which intersect the watershed.

The syWatershed_Block layer is based on 2020 Census blocks with the removal of water blocks and those with no development or data. To create the syWatershed_Block data, a spatial intersect was performed with syWaterShed geometries using the fields described in Table 3-14.

Table 3-14 syWatershed_Block Fields by Data Source

Field Name	Data Source	Description
CensusBlock	TIGER 2021 Census blocks	TIGER 2021 Census block geoid20 value.
HUC	USGS	Watershed HUC-8 value.

For the creation of syHazus State, County, and Tract layers, the output from the dasymetric processing of Census blocks was used to populate the syTract, syCounty, and syState tables. Table 3-15 summarizes the input data and data source information.

Table 3-15 syHazus State, County, and Tract Input Data

Hazus 6.0 Dataset Name	Hazus 6.0 Dataset Date	Hazus 6.0 Dataset Source	Description of Hazus 6.0 Dataset	Geographic Coverage	Previous Data Source (Hazus 5.1)
hzCounty	2022	U.S. Census Bureau	A geodatabase of homogeneous counties.	All U.S.	2010 Census
hzTract	2022	U.S. Census Bureau	A geodatabase of homogeneous tracts.	All U.S.	2010 Census
U.S. Census Bureau TIGER Census Blocks Geodatabase	2021	U.S. Census Bureau	A geodatabase that contains all Census blocks for the nation.	All U.S.	2010 Census

To create the syTract and syCounty tables, geometries and other attributes were pulled from the hzTract and hzCounty tables, respectively. The syState geometries were union-aggregated from the hzCounty geometries. Table 3-16, Table 3-17, and Table 3-18 document the fields for each.

Table 3-16 syTract Fields by Data Source

Field Name	Data Source	Description
Shape	Hazus Program Generated	Shape is provided in GCS WGS84. The shape is the native TIGER Census tract geometry with the exception of modifications made in the vicinity of large lakes and coastal regions.
Tract	TIGER 2021 Tract	A concatenation of the Census tract statefp20, countyfp20 and tractce20 values.
CountyFips	TIGER 2021 Tract	A concatenation of the Census tract statefp20 and countyfp20 values.
Tract6	TIGER 2021 Tract	TIGER 2021 tract tractce20 value.
TractArea	Hazus Program Generated	The calculated area associated with each tract. This value is generated by projecting the geometries into the GCS WGS84 UTM Zone and calculating the areas in square kilometers. These areas represent the entire homogeneous geometries of each tract including both the developed and undeveloped areas.
CenLongit	Hazus Program Generated	Coordinate of each centroid longitude in GCS WGS84.
CenLat	Hazus Program Generated	Coordinate of each centroid latitude in GCS WGS84.

Table 3-17 syCounty Fields by Data Source

Field Name	Data Source	Description
Shape	Hazus Program Generated	Shape is provided in GCS WGS84. The shape is the native TIGER Census tract geometry with the exception of modifications made in the vicinity of large lakes and coastal regions.
CountyFips	TIGER 2021 County	A concatenation of the county's statefp20 and countyfp20 values.
CountyFips3	TIGER 2021 County	TIGER 2021 Tract countyfp20 value.
CountyName	TIGER 2021 County	TIGER 2021 County Name value, in states where duplicate county equivalent names occur (MD, MO, VA) the feature representing the city was updated with the word "City".
State	TIGER 2021 State	TIGER 2021 State stusps value.
StateFips	TIGER 2021 County	TIGER 2021 County statefp20 value.
NumTracts	Hazus Program Generated	The count of Census tracts having dasymetric area within the county.

Field Name	Data Source	Description
TSCounty	Hazus Program Generated	TSCounty is a flag to indicate which counties are supported by the Hazus Tsunami model and available for selection when a Tsunami Study Region is created. The coastal counties for each Tsunami state (CA, OR, WA, AK) that could be impacted by tsunamis includes a flag =1, as well as all counties in HI, all Municipios in PR, and all counties for AS, MP, GU, and VI.

Table 3-18 syState Fields by Data Source

Field Name	Data Source	Description
Shape	Hazus Program Generated	Shape is provided in GCS WGS84. The shape is the native TIGER Census tract geometry with the exception of modifications made in the vicinity of large lakes and coastal regions.
StateFips	TIGER 2021 State	TIGER 2021 State statefp20 value.
StateID	TIGER 2021 State	TIGER 2021 State stusps value.
StateName	TIGER 2021 State	TIGER 2021 State name value.
EorW	Hazus Program Generated	Indicates the state as East or West region for the purpose of mapping to earthquake attenuation functions and source fault modeling capabilities. Value=E/W. For the purpose of attenuation function selection, PR and VI are considered W based on geology.
Region	Hazus Program Generated	Aligns with EorW, 1 denotes W for West, 0 denotes E for East.
NumCounties	Hazus Program Generated	Number of counties within the state.
HUState	Hazus Program Generated	Marks the state as available for Hurricane analysis. Value=0 for non-Hurricane states, 1 for Hurricane states.
TSState	Hazus Program Generated	Marks the state as available for Tsunami analysis. Value=0 for non-Tsunami states, 1 for Tsunami states.

3.5 Site Level Data

The NSI 2022 dataset from the USACE was used as the primary data source for the General Building Stock site level data updates for CONUS, Alaska and Hawaii, and also in the dasymetric boundary revision process as described in the previous section. Data developed by FEMA NHRAP in 2019 for the Hazus 5.0 Caribbean hurricane modeling capability served as the data source for Puerto Rico and the U.S. Virgin Islands (FEMA, 2019).

The site level data development extended beyond spatial features to other Hazus General Building Stock databases, which will be described in more detail in Section 4, Section 5, and Section 6. Table 3-19 summarizes the site-level data used in Hazus 6.0.

Table 3-19 Site Level Data Input Data

Hazus 6.0 Dataset Name	Hazus 6.0 Dataset Date	Hazus 6.0 Dataset Source	Description of Hazus 6.0 Dataset	Geographic Coverage
NSI 2022	June 2022	USACE	Point-based structure inventories. Developed from Lightbox Parcel, NGA lidar, USA Structures and Bing footprints.	AK, HI, CONUS except DC
Income Ratios	June 2022	Hazus Program Generated	Income ratios developed from Census data. Calculated using the block group median income divided by state median income.	CONUS, AK, HI, PR[1]
Census Geometry	June 2022	U.S. Census Bureau	Census block TIGER data	All U.S.
DC Data	June 2022	Open Data DC	Attributes for buildings, building use, police stations and tax/sales information for properties.	DC
PR Data	2019	FEMA NHRAP	Polygon and point data of PR structures, occupancy types.	PR
VI Data	July 2019	FEMA NHRAP	Polygon and point data of VI structures, Income Ratios, and additional attributes.	VI
U.S. Territories Building Footprint Dataset	2018	FEMA NHRAP	Lidar-based polygon building footprints. AS lidar sourced from NOAA (2012). GU lidar sourced from USGS (2012-13) and parcel data from 2007. MP lidar sourced from USACE (2007) and parcel data from 2006.	AS, GU, MP

[1]*No income ratio data were available for the Pacific Territories (AS, GU, MP)*

3.6 District of Columbia General Building Stock Data

Data developed by FEMA NHRAP from Open Data DC data in 2022 was used as the initial data source for the District of Columbia in Hazus. Open Data DC data was used to create the DC dataset for Hazus 6.0 due to lack of Lightbox Parcel data for the District of Columbia. Table 3-20 summarizes the input data used to create the DC data.

Table 3-20 District of Columbia General Building Stock Input Data

Hazus 6.0 Dataset Name	Hazus 6.0 Dataset Date	Hazus 6.0 Dataset Source	Description of Hazus 6.0 Dataset	Geographic Coverage
Computer_Assisted_Mass_Appraisal_-_Commercial.csv	April 2022	Open Data DC	Attribution for commercial.	DC
Computer_Assisted_Mass_Appraisal_-_Residential.csv	April 2022	Open Data DC	Attribution for residential.	DC

Hazus 6.0 Dataset Name	Hazus 6.0 Dataset Date	Hazus 6.0 Dataset Source	Description of Hazus 6.0 Dataset	Geographic Coverage
Computer_Assisted_Mass_Appraisal_-_Condominium.csv	April 2022	Open Data DC	Attribution for condominiums.	DC
Address_Points.csv	April 2022	Open Data DC	Used for address information mostly.	DC
Historical_Data_on_DC_Buildings.shp	April 2022	Open Data DC	Attribution for all.	DC
Property_Use_Code_List_Lookup.csv	April 2022	Open Data DC	Attribution for all.	DC
Existing_Land_Use.shp	May 2022	Open Data DC	Attribution for features that did not have Use Code information from Computer Assisted Mass Appraisal datasets.	DC
Police_Stations.shp	May 2022	Open Data DC	Police station locations in DC.	DC
Integrated_Tax_System_Public_Extract_Property_Sales.csv	April 2022	Open Data DC	Tax and sales info on properties.	DC
Default Full Structure Replacement Cost	Feb 2021	Hazus Program Generated (see Table 6-2)	Default stories and sq ft for Hazus Specific Occupancy Classes.	All U.S.

To process the Open Data DC data for use in Hazus, any buildings noted as demolished before 2002 that did not intersect with the DC Structures building footprint data were filtered out. Historical data polygons were then spatially joined to the address point data. The three Computer Assisted Mass Appraisal csv files (see Table 3-20) were merged together into one file, keeping relevant fields. Additional processing was completed to populate the Use Code fields for properties with structures.

Open Data DC Use Codes for building occupancy were cross-walked over to Hazus specific occupancy classes, adding the short and long descriptions of the property codes, Hazus descriptions, and proxy Story and SqFt attribute information. Additionally, unit number attribution was used for classifying Hazus Specific Occupancy Classes for RES3A-RES3F.

3.7 Pacific Territories Tsunami General Building Stock Data

For American Samoa, Guam, and the Northern Mariana Islands GBS data, Hazus 5.1 data was used as the basis and was enhanced using structure footprints from USA Structures and U.S. Territories Building Footprint data. The availability of building footprint data allowed for improvement of the existing tsNsiGbs data. Review of the data showed that in many places, multiple points overlapped within a single building footprint. To consolidate and remove potential duplications, all existing Hazus 5.1 structures were spatially joined to the closest structure footprint within 30 meters. The structures were then grouped by the Building ID number and then consolidated to a single point represented by the centroid of the building footprint. For information on the attribution of characteristics for these structures, see Section 5.8.

For American Samoa, Guam, and the Northern Mariana Islands, new structures were identified by selecting the footprints from either the USA Structures or U.S. Territories Building Footprint dataset that were further than 30 meters from an existing structure. These structures were then converted from a polygon to point format. Existing Hazus 5.1 structures were removed from the tsNsiGbs table if their locations were not within 30 meters of an USA Structures or U.S. Territories Building Footprint data. For information on the attribution of characteristics for these structures, see Section 5.8.

Section 4. General Building Stock: Occupancy and Building Types

General Building Stock tabular data includes the characteristics of residential, commercial, industrial, agricultural, religious, governmental, and educational buildings. The entire composition within the Census blocks for the Flood Model are assumed to be evenly distributed through the dasymetric blocks which are adjusted through the dasymetric process in prior section.

All four hazard models use common data to ensure that users do not have inventory discrepancies when switching between hazards. The Flood Model displays GBS data at the Census block level, while the Earthquake Model displays GBS data at the Census tract level. To support hurricane surge modeling in Hazus, the Hurricane Model will display and perform analysis at the Census block level if the user selected a combined Hurricane and Flood Study Region.

The key GBS databases include the following (denoting the *Hazus Inventory Technical Manual* section where described):

- *General Occupancy Mapping and Building Types* (Section 4): These data provide a general mapping for the GBS inventory data from the general and specific occupancy to general (e.g., Wood) and specific building types. Generally, all four models agree. However, a user can modify the general occupancy mapping at the Census block level in the Flood Model. Because other models are based on Census tract-level data, modifying the general occupancy mapping at the Census block level will not affect the tract-level results in other models.

- *Building Area by Occupancy* (Section 5): These data are the estimated floor area in square feet by specific occupancy (e.g., COM1). These data are also aggregated for general occupancies (e.g., Residential).

- *Building Count by Occupancy* (Section 5): These data provide the user with an estimated building count by specific occupancy. These data are also aggregated for general occupancies.

- *Other Building Characteristics* (Section 5): These data include the additional GBS supplemental databases used by one or multiple hazards for loss calculations, such as the number of stories, and hazard-specific characteristics like foundation types and First Floor Height Above Grade (FFHAG).

- *Demographics* (Section 5): These data provide housing and population statistics.

- *Building Replacement Value by Occupancy* (Section 6): These data provide the user with estimated replacement values by specific occupancy. These data are also aggregated for general occupancies.

4.1 Occupancy

The primary purpose of building occupancy classifications is to group buildings with similar valuation, damage, and loss characteristics into a set of pre-defined groups for analysis. For example, the damage and loss modules represent a typical response of the occupancy classification to inundation caused by flooding. Table 4-1 shows the 33 specific occupancy classifications used in Hazus.

Table 4-1 Hazus General and Specific Occupancy Classes

Hazus General Occupancy Class	Hazus Specific Occupancy Class	Class Description
Residential	RES1	Single-family Dwelling
Residential	RES2	Mobile Home
Residential	RES3A	Multi-Family Dwelling – Duplex
Residential	RES3B	Multi-Family Dwelling – 3-4 Units
Residential	RES3C	Multi-Family Dwelling – 5-9 Units
Residential	RES3D	Multi-Family Dwelling – 10-19 Units
Residential	RES3E	Multi-Family Dwelling – 20-49 Units
Residential	RES3F	Multi-Family Dwelling – 50+ Units
Residential	RES4	Temporary Lodging
Residential	RES5	Institutional Dormitory
Residential	RES6	Nursing Home
Commercial	COM1	Retail Trade
Commercial	COM2	Wholesale Trade
Commercial	COM3	Personal and Repair Services
Commercial	COM4	Business/Professional/Technical Services
Commercial	COM5	Depository Institutions (Banks)
Commercial	COM6	Hospital
Commercial	COM7	Medical Office/Clinic
Commercial	COM8	Entertainment & Recreation
Commercial	COM9	Theaters
Commercial	COM10	Parking
Industrial	IND1	Heavy
Industrial	IND2	Light
Industrial	IND3	Food/Drugs/Chemicals
Industrial	IND4	Metals/Minerals Processing
Industrial	IND5	High Technology
Industrial	IND6	Construction
Agriculture	AGR1	Agriculture
Religion	REL1	Church/Non-Profit
Government	GOV1	General Services
Government	GOV2	Emergency Response
Education	EDU1	Schools/Libraries
Education	EDU2	Colleges/Universities

During a review of NSI 2022 data, it was determined that structures identified with the North American Industry Classification System (NAICS) Codes 721310, 922140, 561210 had misassigned occupancy types, which were re-categorized to RES5 for Hazus.

4.2 Building Types

Each of the four Hazus Models uses different schemes related to building types. While each hazard has the same five general building types of Wood Frame, Steel Frame, Concrete, Masonry, and Manufactured Housing, the specific building types (SBTs) differ by hazard.

4.2.1 Earthquake and Tsunami Specific Building Types

Table 4-2 lists the 36 model SBTs used by the Earthquake and Tsunami Models. These specific building types are based on the classification system of FEMA 178, *NEHRP Handbook for the Seismic Evaluation of Existing Buildings* (FEMA, 1992) and may be found in more recent ASCE publications, including *FEMA 310, Handbook for the Seismic Evaluation of Buildings–A Prestandard* (FEMA, 1998). In addition, the Methodology breaks down FEMA 178 classes into height ranges and includes mobile homes.

Table 4-2 Earthquake and Tsunami Model Specific Building Types

Specific Building Type Label	Description	Height Range - Name	Height Range - Stories	Typical Height - Stories	Typical Height - Feet
W1	Wood, Light Frame (≤ 5,000 ft^2)	N/A	1 – 2	1	14
W2	Wood, Commercial & Industrial (> 5,000 ft^2)	N/A	All	2	24
S1L	Steel Moment Frame	Low-Rise	1 – 3	2	24
S1M	Steel Moment Frame	Mid-Rise	4 – 7	5	60
S1H	Steel Moment Frame	High-Rise	8+	13	156
S2L	Steel Braced Frame	Low-Rise	1 – 3	2	24
S2M	Steel Braced Frame	Mid-Rise	4 – 7	5	60
S2H	Steel Braced Frame	High-Rise	8+	13	156
S3	Steel Light Frame	N/A	All	1	15
S4L	Steel Frame with Cast-in-Place Concrete Shear Walls	Low-Rise	1 – 3	2	24
S4M	Steel Frame with Cast-in-Place Concrete Shear Walls	Mid-Rise	4 – 7	5	60
S4H	Steel Frame with Cast-in-Place Concrete Shear Walls	High-Rise	8+	13	156

Specific Building Type Label	Description	Height Range - Name	Height Range - Stories	Typical Height - Stories	Typical Height - Feet
S5L	Steel Frame with Unreinforced Masonry Infill Walls	Low-Rise	1 – 3	2	24
S5M	Steel Frame with Unreinforced Masonry Infill Walls	Mid-Rise	4 – 7	5	60
S5H	Steel Frame with Unreinforced Masonry Infill Walls	High-Rise	8+	13	156
C1L	Concrete Moment Frame	Low-Rise	1 – 3	2	20
C1M	Concrete Moment Frame	Mid-Rise	4 – 7	5	50
C1H	Concrete Moment Frame	High-Rise	8+	12	120
C2L	Concrete Shear Walls	Low-Rise	1 – 3	2	20
C2M	Concrete Shear Walls	Mid-Rise	4 – 7	5	50
C2H	Concrete Shear Walls	High-Rise	8+	12	120
C3L	Concrete Frame with Unreinforced Masonry Infill Walls	Low-Rise	1 – 3	2	20
C3M	Concrete Frame with Unreinforced Masonry Infill Walls	Mid-Rise	4 – 7	5	50
C3H	Concrete Frame with Unreinforced Masonry Infill Walls	High-Rise	8+	12	120
PC1	Precast Concrete Tilt-Up Walls	N/A	All	1	15
PC2L	Precast Concrete Frames with Concrete Shear Walls	Low-Rise	1 – 3	2	20
PC2M	Precast Concrete Frames with Concrete Shear Walls	Mid-Rise	4 – 7	5	50
PC2H	Precast Concrete Frames with Concrete Shear Walls	High-Rise	8+	12	120
RM1L	Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms	Low-Rise	1-3	2	20

Specific Building Type Label	Description	Height Range - Name	Height Range - Stories	Typical Height - Stories	Typical Height - Feet
RM1M	Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms	Mid-Rise	4+	5	50
RM2L	Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms	Low-Rise	1 – 3	2	20
RM2M	Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms	Mid-Rise	4 – 7	5	50
RM2H	Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms	High-Rise	8+	12	120
URML	Unreinforced Masonry Bearing Walls	Low-Rise	1 – 2	1	15
URMM	Unreinforced Masonry Bearing Walls	Mid-Rise	3+	3	35
MH	Mobile Homes	N/A	All	1	10

A general description of each of the 16 structural systems of specific building types is provided below.

4.2.1.1 WOOD, LIGHT FRAME (W1)

These are typically single-family or small, multi-family dwellings of not more than 5,000 square feet of floor area. The essential structural feature of these buildings is repetitive framing by wood rafters or joists on wood stud walls. Loads are light and spans are small. These buildings may have relatively heavy masonry chimneys and may be partially or fully covered with masonry veneer. Most of these buildings, especially the single-family residences, are not engineered but constructed in accordance with “conventional construction” provisions of building codes. Hence, they usually have the components of a lateral-force-resisting system even though it may be incomplete. Lateral loads are transferred by diaphragms to shear walls. The diaphragms are roof panels and floors that may be sheathed with sawn lumber, plywood, or fiberboard sheathing. Shear walls are sheathed with boards, stucco, plaster, plywood, gypsum board, particle board, or fiberboard, or interior partition walls sheathed with plaster or gypsum board.

4.2.1.2 WOOD, GREATER THAN 5,000 FT^2 (W2)

These buildings are typically commercial or industrial buildings, or multi-family residential buildings with a floor area greater than 5,000 square feet. These buildings include structural systems framed by beams or major horizontally spanning members over columns. These horizontal members may be glue-laminated (glu-lam) wood, solid-sawn wood beams, or wood trusses, or steel beams or trusses. Lateral loads usually are resisted by wood diaphragms and exterior walls sheathed with plywood, stucco, plaster, or other paneling. The walls may have diagonal rod bracing. Large openings for stores and garages often require post-and-beam framing. Lateral load resistance on those lines may be achieved with steel rigid frames (moment frames) or diagonal bracing.

4.2.1.3 STEEL MOMENT FRAME (S1)

These buildings have a frame of steel columns and beams. In some cases, the beam-column connections have very small moment resisting capacity but, in other cases, some of the beams and columns are fully developed as moment frames to resist lateral forces. Usually, the structure is concealed on the outside by exterior nonstructural walls, which can be of almost any material (curtain walls, brick masonry, or precast concrete panels), and on the inside by ceilings and column furring. Diaphragms transfer lateral loads to moment-resisting frames. The diaphragms can be almost any material. The frames develop their stiffness by full or partial moment connections. The frames can be located almost anywhere in the building. Usually, the columns have their strong directions oriented, so some columns act primarily in one direction while the others act in the other direction. Steel moment frame buildings are typically more flexible than shear wall buildings. This low stiffness can result in large inter-story drifts that may lead to relatively greater nonstructural damage.

4.2.1.4 STEEL BRACED FRAME (S2)

These buildings are like steel moment frame buildings except that the vertical components of the lateral-force-resisting system are braced frames rather than moment frames.

4.2.1.5 STEEL LIGHT FRAME (S3)

These buildings are pre-engineered and prefabricated with transverse rigid frames. The roof and walls consist of lightweight panels, usually corrugated metal. The frames are designed for maximum efficiency, often with tapered beam and column sections built up of light steel plates. The frames are built in segments and assembled in the field with bolted joints. Lateral loads in the transverse direction are resisted by the rigid frames with loads distributed to them by diaphragm elements, typically rod-braced steel roof framing bays. Tension rod bracing typically resists loads in the longitudinal direction.

4.2.1.6 STEEL FRAME WITH CAST-IN-PLACE CONCRETE SHEAR WALLS (S4)

The shear walls in these buildings are cast-in-place concrete and may be bearing walls. The steel frame is designed for vertical loads only. Diaphragms of almost any material transfer lateral loads to the shear walls. The steel frame may provide a secondary lateral-force-resisting system depending on the stiffness of the frame and the moment capacity of the beam-column connections. In modern “dual” systems, the steel moment frames are designed to work together with the concrete shear walls.

4.2.1.7 STEEL FRAME WITH UNREINFORCED MASONRY INFILL WALLS (S5)

This is one of the older types of buildings. The infill walls usually are offset from the exterior frame members, wrap around them, and present a smooth masonry exterior with no indication of the frame. Solidly infilled masonry panels, when they fully engage the surrounding frame members (i.e., lie in the same plane), may provide stiffness and lateral load resistance to the structure.

4.2.1.8 REINFORCED CONCRETE MOMENT RESISTING FRAMES (C1)

These buildings are like steel moment frame buildings except that the frames are reinforced concrete. There are a large variety of frame systems. Some older concrete frames may be proportioned and detailed such that brittle failure of the frame members can occur in earthquakes, leading to a partial or full collapse of the buildings. Modern frames in zones of high seismicity are proportioned and detailed for ductile behavior and are likely to undergo large deformations during an earthquake without brittle failure of frame members and collapse.

4.2.1.9 CONCRETE SHEAR WALLS (C2)

The vertical components of the lateral force-resisting system in these buildings are concrete shear walls that are usually bearing walls. In older buildings, the walls often are quite extensive, and the wall stresses are low, but reinforcing is light. In newer buildings, the shear walls often are limited in extent, generating concerns about boundary members and overturning forces.

4.2.1.10 CONCRETE FRAME BUILDINGS WITH UNREINFORCED MASONRY INFILL WALLS (C3)

These buildings are like steel frame buildings with unreinforced masonry infill walls except that the frame is of reinforced concrete. In these buildings, the shear strength of the columns, after cracking of the infill, may limit the semi-ductile behavior of the system.

4.2.1.11 PRECAST CONCRETE TILT-UP WALLS (PC1)

These buildings have a wood or metal deck roof diaphragm, which often is very large, distributing lateral forces to precast concrete shear walls. The walls are thin but relatively heavy, while the roofs are relatively light. Older or non-seismic-code buildings often have inadequate connections for the anchorage of the walls to the roof for out-of-plane forces, and the panel connections are often brittle. Tilt-up buildings are usually one or two stories in height. Walls can have numerous openings for doors and windows of such size that the wall looks more like a frame than a shear wall.

4.2.1.12 PRECAST CONCRETE FRAMES WITH CONCRETE SHEAR WALLS (PC2)

These buildings contain floor and roof diaphragms, typically composed of precast concrete elements with or without cast-in-place concrete topping slabs. Precast concrete girders and columns support the diaphragms. The girders often bear on column corbels. Closure strips between precast floor elements and beam-column joints are usually cast-in-place concrete. Welded steel inserts are often used to interconnect precast elements. Precast or cast-in-place concrete shear walls resist lateral loads. For buildings with precast frames and concrete shear walls to perform well, the details used to connect the structural elements must have enough strength and displacement capacity; however, in some cases, the connection details between the precast elements have negligible ductility.

4.2.1.13 REINFORCED MASONRY BEARING WALLS WITH WOOD OR METAL DECK DIAPHRAGMS (RM1)

These buildings have perimeter bearing walls of reinforced brick or concrete-block masonry. These walls are the vertical elements in the lateral-force-resisting system. The floors and roofs are framed with wood joists and beams either with plywood or braced sheathing, the latter either straight or diagonally sheathed, or with steel beams with metal deck with or without concrete fill. Interior wood posts or steel columns support wood floor framing; steel columns support steel beams.

4.2.1.14 REINFORCED MASONRY BEARING WALLS WITH PRECAST CONCRETE DIAPHRAGMS (RM2)

These buildings have bearing walls like those of reinforced masonry bearing wall structures with wood or metal deck diaphragms, but the roof and floors are composed of precast concrete elements such as planks or tee-beams and the precast roof and floor elements are supported on interior beams and columns of steel or concrete (cast-in-place or precast). The precast horizontal elements often have a cast-in-place topping.

4.2.1.15 UNREINFORCED MASONRY BEARING WALLS (URM)

These buildings include structural elements that vary depending on the building's age and, to a lesser extent, its geographic location. In buildings built before 1900, the majority of floor and roof construction consists of wood sheathing supported by wood framing. In large multistory buildings, the floors are cast-in-place concrete supported by the unreinforced masonry walls and/or steel or concrete interior framing. In unreinforced masonry constructed after 1950 outside California, wood floors usually have plywood rather than board sheathing. In regions of lower seismicity, buildings of this type constructed more recently can include floor and roof framing consisting of metal deck and concrete fill supported by steel framing elements. The perimeter walls, and possibly some interior walls, are unreinforced masonry. The walls may or may not be anchored to the diaphragms. Ties between the walls and diaphragms are more common for the bearing walls than for walls parallel to the floor framing. Roof ties are usually less common and more erratically spaced than those at the floor levels. Interior partitions that interconnect the floors and roof can reduce diaphragm displacements.

One additional note in earthquake specific building type exposures for Puerto Rico and the U.S. Virgin Islands; the default distributions have been adjusted resulting in fewer concrete and more unreinforced masonry single family homes based on local expertise and the known prevalence of informal construction (FEMA, 2021a). These changes are reflected in Appendix A.

4.2.1.16 MOBILE HOMES (MH)

These are prefabricated housing units trucked to the site and placed on isolated piers, jack stands, or masonry block foundations (usually without any positive anchorage). Floors and roofs of mobile homes are usually constructed with plywood and outside surfaces are covered with sheet metal.

4.2.2 Flood Specific Building Types

Although most flood depth-damage functions are independent of structural system or construction material, the Hazus inventory database includes SBT as a basic parameter because of the importance of structure type on the estimation of earthquake, tsunami, and hurricane damage. Within the Flood Model, the SBTs are a simplified version of the ones used by the Earthquake Model and are listed in Table 4-3.

Table 4-3 Flood Model Specific Building Types

Specific Building Type Label	Description	Height Range - Name	Height Range - Stories	Typical Height - Stories	Typical Height - Feet
Wood (W)	Wood (light frame, commercial and industrial)	N/A	All	1 to 2	14 to 24
Steel (S)	Steel frame structures including those with infill walls or concrete shear walls	Low-Rise	1 – 3	2	24
		Mid-Rise	4 – 7	5	60
		High-Rise	8+	13	156
Concrete (C)	Concrete frame or shear wall structures including tilt-up, precast, and infill walls	Low-Rise– 1 - 3	2	20	20
		Mid-Rise– 4 - 7	5	50	50
		High-Rise	8+	12	120
Masonry (M)	All structures with masonry bearing walls	Low-Rise– 1 - 3	2	20	20
		Mid-Rise– 4 - 7	5	50	50
		High-Rise	8+	12	120
Manufactured Housing (MH)	Manufactured Housing	N/A	All	1	10

A general discussion of the five specific building types for flood modeling is provided below.

4.2.2.1 WOOD (W)

Within Hazus, there are two general types of wood structures: 1) small, multi-family or single-family dwellings of not more than 5,000 square feet of floor area; and 2) large multi-family, commercial, or industrial buildings of more than 5,000 square feet of floor area. The essential structural feature of the smaller (5,000 square feet or less) buildings is repetitive framing by wood rafters or joists on wood stud walls. These buildings may have masonry chimneys and may be partially or fully covered with masonry veneer. Most of these buildings, especially the single-family residences, are not engineered but are constructed in accordance with “conventional construction” provisions of building codes. The floors and roofs may be sheathed with sawn lumber, plywood, or fiberboard sheathing. Walls are covered with boards, stucco, plaster, plywood, gypsum board, particleboard, or fiberboard, or a combination of several materials. Interior partition walls are usually covered with plaster or gypsum board.

The larger buildings (floor areas greater than 5,000 square feet) have framing systems consisting of beams or major horizontal members spanning between columns supporting lighter floor joists or rafters. These horizontal members may be glue-laminated wood, solid-sawn wood beams, wood or steel trusses, or steel beams. The exterior walls are covered with plywood, stucco, plaster, other types of paneling, or a combination of materials. The interior surfaces of the walls and interior partitions usually are covered with gypsum board or plaster.

4.2.2.2 STEEL (S)

Steel buildings are usually framed with a series of steel girders spanning between steel columns supporting beams and various forms of wood or concrete floors and roof. Exterior walls are constructed of steel siding, window walls, or cladding panels, but may include cast-in-place concrete shear walls or unreinforced masonry infill walls. If ceilings are used in these buildings, they are usually suspended acoustical tiles. These buildings most commonly accommodate offices, warehouses, commercial, or industrial occupancies.

4.2.2.3 CONCRETE (C)

Concrete buildings are those where the structural frames and/or exterior walls are made of reinforced concrete, either cast-in-place, pre-cast tilt-up, or pre-cast elements. Interior framing can be steel, wood, concrete, pre-cast, or any combination. These buildings are most commonly used for office, warehouse, commercial, or industrial occupancies. Interior finishes are usually concrete, gypsum board, or plaster.

4.2.2.4 MASONRY (M)

Masonry buildings are those where the exterior walls are masonry, either reinforced or unreinforced. These buildings are most commonly used for office, warehouse, commercial, industrial, or multi-family occupancies. Interior finishes are usually concrete, gypsum board, or plaster.

4.2.2.5 MANUFACTURED HOUSING (MH)

These are prefabricated housing units that are trucked to the site and then placed on isolated piers, jack stands, or masonry block foundations (usually without any positive anchorage). Floors and roofs of mobile homes usually are constructed with plywood and outside surfaces are covered with sheet metal.

4.2.3 Hurricane Specific Building Types

The 39 SBTs used in the Hurricane Model are listed and briefly described in Table 4-4. Each identifier begins with W, M, C, S, or MH, representing the general building type to which the SBT belongs.

Table 4-4 Hurricane Model Specific Building Types

Specific Building Type Label	Description
WSF1	Wood, Single-family, One-story
WSF2	Wood, Single-family, Two or More Stories
WMUH1	Wood, Multi-Unit Housing, One-story
WMUH2	Wood, Multi-Unit Housing, Two Stories
WMUH3	Wood, Multi-Unit Housing, Three or More Stories
MSF1	Masonry, Single-family, One-story
MSF2	Masonry, Single-family, Two or More Stories
MMUH1	Masonry, Multi-Unit Housing, One-story
MMUH2	Masonry, Multi-Unit Housing, Two Stories

Specific Building Type Label	Description
MMUH3	Masonry, Multi-Unit Housing, Three or More Stories
MLRM1	Masonry, Low-Rise Strip Mall, Up to 15 Feet
MLRM2	Masonry, Low-Rise Strip Mall, More than 15 Feet
MLRI	Masonry, Low-Rise Industrial/Warehouse/Factory Buildings
MERBL	Masonry, Engineered Residential Building, Low-Rise (1-2 Stories)
MERBM	Masonry, Engineered Residential Building, Mid-Rise (3-5 Stories)
MERBH	Masonry, Engineered Residential Building, High-Rise (6+ Stories)
MECBL	Masonry, Engineered Commercial Building, Low-Rise (1-2 Stories)
MECBM	Masonry, Engineered Commercial Building, Mid-Rise (3-5 Stories)
MECBH	Masonry, Engineered Commercial Building, High-Rise (6+ Stories)
CERBL	Concrete, Engineered Residential Building, Low-Rise (1-2 Stories)
CERBM	Concrete, Engineered Residential Building, Mid-Rise (3-5 Stories)
CERBH	Concrete, Engineered Residential Building, High-Rise (6+ Stories)
CECBL	Concrete, Engineered Commercial Building, Low-Rise (1-2 Stories)
CECBM	Concrete, Engineered Commercial Building, Mid-Rise (3-5 Stories)
CECBH	Concrete, Engineered Commercial Building, High-Rise (6+ Stories)
SPMBS	Steel, Pre-Engineered Metal Building, Small
SPMBM	Steel, Pre-Engineered Metal Building, Medium
SPMBL	Steel, Pre-Engineered Metal Building, Large
SERBL	Steel, Engineered Residential Building, Low-Rise (1-2 Stories)
SERBM	Steel, Engineered Residential Building, Mid-Rise (3-5 Stories)
SERBH	Steel, Engineered Residential Building, High-Rise (6+ Stories)
SECBL	Steel, Engineered Commercial Building, Low-Rise (1-2 Stories)
SECBM	Steel, Engineered Commercial Building, Mid-Rise (3-5 Stories)
SECBH	Steel, Engineered Commercial Building, High-Rise (6+ Stories)
MHPHUD	Manufactured Home, Pre-Housing and Urban Development (HUD)
MH76HUD	Manufactured Home, 1976 HUD
MH94HUD-I	Manufactured Home, 1994– HUD - Wind Zone I
MH94HUD-II	Manufactured Home, 1994– HUD - Wind Zone II
MH94HUD-III	Manufactured Home, 1994– HUD - Wind Zone III

The descriptions of the 39 Hurricane specific building types are provided below.

4.2.3.1 WOOD, SINGLE-FAMILY, ONE-STORY (WSF1)

The WSF1 model building is a wood-framed, single-story, single-family house. This class also includes additional subclasses reflecting different roof types added for the Caribbean (FEMA, 2021a).

4.2.3.2 WOOD, SINGLE-FAMILY, TWO OR MORE STORIES (WSF2)

The WSF2 model building is a wood-framed, two-story, single-family house. This class also includes additional subclasses reflecting different roof types added for the Caribbean (FEMA, 2021a).

4.2.3.3 WOOD, MULTI-UNIT HOUSING, ONE-STORY (WMUH1)

The WMUH1 model building is a wood-framed, single-story, marginally engineered or non-engineered, multi-family dwelling or hotel/motel.

4.2.3.4 WOOD, MULTI-UNIT HOUSING, TWO STORIES (WMUH2)

The WMUH2 model building is a wood-framed, two-story, marginally engineered or non-engineered, multi-family dwelling or hotel/motel.

4.2.3.5 WOOD, MULTI-UNIT HOUSING, THREE OR MORE STORIES (WMUH3)

The WMUH3 model building is a wood-framed, three-story, marginally engineered or non-engineered, multi-family dwelling or hotel/motel.

4.2.3.6 MASONRY, SINGLE-FAMILY, ONE-STORY (MSF1)

The MSF1 model building is a masonry wall, single-story, single-family house. The masonry walls can be either reinforced or unreinforced. This class also include additional subclasses reflecting different roof types added for the Caribbean (FEMA, 2021a).

4.2.3.7 MASONRY, SINGLE-FAMILY, TWO OR MORE STORIES (MSF2)

The MSF2 model building is a masonry wall, two-story, single-family house. The masonry walls can be either reinforced or unreinforced. This class also include additional subclasses reflecting different roof types added for the Caribbean (FEMA, 2021a).

4.2.3.8 MASONRY, MULTI-UNIT HOUSING, 1-STORY (MMUH1)

The MMUH1 model building is a masonry wall, single-story, marginally engineered or non-engineered, multi-family dwelling or hotel/motel. The masonry walls can be either reinforced or unreinforced.

4.2.3.9 MASONRY, MULTI-UNIT HOUSING, TWO STORIES (MMUH2)

The MMUH2 model building is a masonry wall, single-story, marginally engineered or non-engineered, multi-family dwelling or hotel/motel. The masonry walls can be either reinforced or unreinforced.

4.2.3.10 MASONRY, MULTI-UNIT HOUSING, THREE OR MORE STORIES (MMUH3)

The MMUH3 model building is a masonry wall, single-story, marginally engineered or non-engineered, multi-family dwelling or hotel/motel. The masonry walls can be either reinforced or unreinforced.

4.2.3.11 MASONRY, LOW-RISE STRIP MALL, UP TO 15 FEET (MLRM1)

The MLRM1 model building is a masonry wall, low-rise strip mall building, up to 15 feet in height. The masonry walls can be either reinforced or unreinforced.

4.2.3.12 MASONRY, LOW-RISE STRIP MALL, MORE THAN 15 FEET (MLRM2)

The MLRM2 model building is a masonry wall, low-rise strip mall building, more than 15 feet in height. The masonry walls can be either reinforced or unreinforced.

4.2.3.13 MASONRY, LOW-RISE INDUSTRIAL/WAREHOUSE/FACTORY BUILDINGS (MLRI)

The MLRI model building is a 240,000 square foot, masonry wall, industrial building or warehouse. The masonry walls can be either reinforced or unreinforced.

4.2.3.14 MASONRY, ENGINEERED RESIDENTIAL BUILDING, LOW-RISE (MERBL)

The MERBL model building is a two-story, engineered, reinforced masonry wall, residential building with a compartmented floor plan.

4.2.3.15 MASONRY, ENGINEERED RESIDENTIAL BUILDING, MID-RISE (MERBM)

The MERBM model building is a five-story, engineered, reinforced masonry wall, residential building with a compartmented floor plan.

4.2.3.16 MASONRY, ENGINEERED RESIDENTIAL BUILDING, HIGH-RISE (MERBH)

The MERBH model building is an eight-story, engineered, reinforced masonry wall, residential building with a compartmented floor plan.

4.2.3.17 MASONRY, ENGINEERED COMMERCIAL BUILDING, LOW-RISE (MECBL)

The MECBL model building is a two-story, engineered, reinforced masonry wall, commercial building with an open floor plan.

4.2.3.18 MASONRY, ENGINEERED COMMERCIAL BUILDING, MID-RISE (MECBM)

The MECBM model building is a five-story, engineered, reinforced masonry wall, commercial building with an open floor plan.

4.2.3.19 MASONRY, ENGINEERED COMMERCIAL BUILDING, HIGH-RISE (MECBH)

The MECBH model building is an eight-story, engineered, reinforced masonry wall, commercial building with an open floor plan.

4.2.3.20 CONCRETE, ENGINEERED RESIDENTIAL BUILDING, LOW-RISE (CERBL)

The CERBL model building is a two-story, engineered, reinforced concrete, residential building with a compartmented floor plan.

4.2.3.21 CONCRETE, ENGINEERED RESIDENTIAL BUILDING, MID-RISE (CERBM)

The CERBM model building is a five-story, engineered, reinforced concrete, residential building with a compartmented floor plan.

4.2.3.22 CONCRETE, ENGINEERED RESIDENTIAL BUILDING, HIGH-RISE (CERBH)

The CERBH model building is an eight-story, engineered, reinforced concrete, residential building with a compartmented floor plan.

4.2.3.23 CONCRETE, ENGINEERED COMMERCIAL BUILDING, LOW-RISE (CECBL)

The CECBL model building is a two-story, engineered, reinforced concrete, commercial building with an open floor plan.

4.2.3.24 CONCRETE, ENGINEERED COMMERCIAL BUILDING, MID-RISE (CECBM)

The CECBM model building is a five-story, engineered, reinforced concrete, commercial building with an open floor plan.

4.2.3.25 CONCRETE, ENGINEERED COMMERCIAL BUILDING, HIGH-RISE (CECBH)

The CECBH model building is an eight-story, engineered, reinforced concrete, commercial building with an open floor plan.

4.2.3.26 STEEL, PRE-ENGINEERED METAL BUILDING, SMALL (SPMBS)

The SPMBS model building is a 4,000 square foot, pre-engineered, steel frame, metal clad building.

4.2.3.27 STEEL, PRE-ENGINEERED METAL BUILDING, MEDIUM (SPMBM)

The SPMBS model building is a 50,000 square foot, pre-engineered, steel frame, metal clad building.

4.2.3.28 STEEL, PRE-ENGINEERED METAL BUILDING, LARGE (SPMBL)

The SPMBL model building is a 500,000 square foot, pre-engineered, steel frame, metal clad building.

4.2.3.29 STEEL, ENGINEERED RESIDENTIAL BUILDING, LOW-RISE (SERBL)

The SERBL model building is a two-story, engineered, steel frame, residential building with a compartmented floor plan.

4.2.3.30 STEEL, ENGINEERED RESIDENTIAL BUILDING, MID-RISE (SERBM)

The SERBM model building is a five-story, engineered, steel frame, residential building with a compartmented floor plan.

4.2.3.31 STEEL, ENGINEERED RESIDENTIAL BUILDING, HIGH-RISE (SERBH)

The SERBH model building is an eight-story, engineered, steel frame, residential building with a compartmented floor plan.

4.2.3.32 STEEL, ENGINEERED COMMERCIAL BUILDING, LOW-RISE (SECBL)

The SECBL model building is a two-story, engineered, steel frame, commercial building with an open floor plan.

4.2.3.33 STEEL, ENGINEERED COMMERCIAL BUILDING, MID-RISE (SECBM)

The SECBM model building is a five-story, engineered, steel frame, commercial building with an open floor plan.

4.2.3.34 STEEL, ENGINEERED COMMERCIAL BUILDING, HIGH-RISE (SECBH)

The SECBH model building is an eight-story, engineered, steel frame, commercial building with an open floor plan.

4.2.3.35 MANUFACTURED HOME, PRE-HUD (MHPHUD)

The MHPHUD model building is a manufactured home built prior to the 1976 HUD standard. The home can be either tied-down or unrestrained.

4.2.3.36 MANUFACTURED HOME, 1976 HUD (MH76HUD)

The MH76HUD model building is a manufactured home built to the 1976 HUD standard. The home can be either tied-down or unrestrained.

4.2.3.37 MANUFACTURED HOME, 1994 HUD REGION I (MH94HUD-I)

The MH94HUD-I model building is a manufactured home built to the 1994 HUD standard for Wind Zone I. The home can be either tied-down or unrestrained.

4.2.3.38 MANUFACTURED HOME, 1994 HUD REGION II (MH94HUD-II)

The MH94HUD-II model building is a manufactured home built to the 1994 HUD standard for Wind Zone II. The home can be either tied-down or unrestrained.

4.2.3.39 MANUFACTURED HOME, 1994 HUD REGION III (MH94HUD-III)

The MH94HUD-III model building is a manufactured home built to the 1994 HUD standard for Wind Zone III. The home can be either tied-down or unrestrained.

Section 5. General Building Stock: Baseline Database for Building Characteristics

The Hazus Occupancy and Building Types provide the framework for establishing the detailed Hazus baseline database for building characteristics. This section provides details on each of the main GBS tabular database elements, including background information on how the database was developed. Table 5-1 provides a general overview of the current status of the major GBS tabular database elements by data type, hazard, and sources. Section 3 provides additional information on the geographic coverage of Hazus data.

Table 5-1 Baseline General Building Stock Database Summary Table

Tabular Data Type	Data Element	Hazards	Hazus 6.1 Dataset Source	Hazus 6.1 Dataset Date
Building Count	Building Count by Specific Occupancy	All	NSI 2022 (USACE)	2022
Building Area	Building Area by Specific Occupancy	All	NSI 2022 (USACE)	2022
Specific Occupancy to General Building Type	Mapping Scheme: Specific Occupancy to Gen. Bldg. Type	All	FEMA (2023)[1], Applied Technology Council (ATC) 13 (ATC, 1985),	2023, 1985
EQ General Building Type to EQ Specific Bldg. Type and Design Level	Mapping Scheme: Gen. Bldg. Type to EQ Spec. Bldg. Type and EQ Design Level	EQ, TS	FEMA (2023)[1],ATC 13 (ATC, 1985); NSI 2022 (USACE), Los Angeles County Assessor 2023, Riverside County Assessor 2023, Sacramento County Assessor 2023, San Bernardino County Assessor 2023, San Diego County Assessor 2023, San Francisco County Assessor 2023, San Joaquin County Assessor 2023, Tehama County Assessor 2023	2023, 1985, 2022

Tabular Data Type	Data Element	Hazards	Hazus 6.1 Dataset Source	Hazus 6.1 Dataset Date
EQ Specific Building Type to Foundation Type	Mapping Scheme: Spec. Bldg. Type to Foundation Type	EQ, TS	Department of Energy (DOE)	1997
FL Specific Occupancy to Foundation Type	Mapping Scheme: Foundation Types to Specific Occupancy	FL, TS	DOE Reports	1997
HU General Building Type to HU Specific Building Type	Mapping Scheme: Gen. Bldg. Type to HU Spec. Bldg. Type	HU	Florida Residential Construction Mitigation Program (RCMP) database and Contractor Surveys[2]	1999 (CONUS) 2001 (HI) 2021 (PR, VI)
HU Specific Building Type to HU Wind Characteristics	Mapping Scheme: HU Spec. Bldg. Type to Wind Characteristics	HU	Florida RCMP database and Contractor Surveys[2]	1999 (CONUS) 2001 (HI) 2021 (PR, VI)

[1]Updates for EQ in 2023 for all States and Territories were based on individual structure data from NSI 2022, Lightbox and California parcel data derived construction years and building types. Height and number of stories data from Open Street Map, USA Structures, and Skyscrapers.com (FEMA, 2023, this Inventory Technical Manual update).
[2]Updates in 2001 for Hawaii (ARA, 2001) and 2021 fo Puerto Rico and U.S. Virgin Islands (FEMA, 2021a) were based on individual structure data and were not developed using the same methods as other Census GBS and NSI data.

5.1 Background

Hazus 6.0 uses NSI 2022 data, 2020 Census data and primarily 2022 economic values. The valuations were updated at the structure level. The NSI 2022 is a more robust data source and includes many structure-level attributes to identify a structure's number of stories, type of basement, and other features when available (USACE, 2022). Although the current availability of the NSI 2022 data is not yet nationwide and Hazus weighting factors are still in use, in regions where the NSI 2022 data is available it has allowed for more precise evaluations.

Table 5-2 describes the input data used to develop the updated GBS dataset.

Table 5-1 General Building Stock Input Data

Hazus 6.1 Dataset Name	Hazus 6.1 Dataset Date	Hazus 6.1 Dataset Source	Description of Hazus 6.1 Dataset	Geographic Coverage	Previous Data Source (Hazus 5.1)
NSI 2022	June 2022	USACE	Point-based structure inventories. Developed from Lightbox Parcel, NGA lidar, USA Structures and Bing footprints.	AK, HI, CONUS except DC	2010 Census and 2006 Dun & Bradstreet
DC Data	June 2022	FEMA NHRAP	Dataset developed from Open Data DC due to the lack of Lightbox Parcel Data for DC.	DC	2010 Census and 2006 Dun & Bradstreet

Hazus 6.1 Dataset Name	Hazus 6.1 Dataset Date	Hazus 6.1 Dataset Source	Description of Hazus 6.1 Dataset	Geographic Coverage	Previous Data Source (Hazus 5.1)
PR Data	2019	FEMA NHRAP	Polygon and point data of PR structures, occupancy types.	PR	U.S. Census Bureau
VI Data	July 2019	FEMA NHRAP	Polygon and point data of VI structures, Income Ratios, and additional attributes.	VI	Census and Landscan
Hazus College & University (EDU2) database	May 2022	Hazus Program Generated	Created from: 2022 HIFLD Open data, 2019 hzTract, 2022 hzCountyLocationFactor (see Section 6.3) and 2022 College and University Replacement Cost Model (see Section 7.2.5.3.) Provides structure level EDU2 data. The number of students field to use is 'NumStudents. This file is used to replace the NSI 2022 EDU2 data.	All U.S.	2010 Census, 2006 Dun & Bradstreet, and NSI 1.0 (for Tsunami GBS only)
Income Ratios	June 2022	Hazus Program Generated	Income ratios developed from Census data. Calculated using the block group median income divided by state median income.	CONUS, AK, HI, PR[1]	U.S. Census Bureau
Hazus Replacement Cost Model and other Economic Models	2022	Hazus Program Generated	Replacement cost values to calculate the valuation of structures and content, models for commercial inventory value and business interruption loss parameters (rent, relocation, income and wages). Uses data from U.S. Census 2020 Manufactured Housing Survey Annual Data (for RES2), Bureau of Economic Analysis (BEA)(2022a and b) and Bureau of Labor Statistics (BLS) (2022). See Section 6.	All U.S.	2018 Replacement Cost Methodology

Hazus 6.1 Dataset Name	Hazus 6.1 Dataset Date	Hazus 6.1 Dataset Source	Description of Hazus 6.1 Dataset	Geographic Coverage	Previous Data Source (Hazus 5.1)
Building Type Data	2023	Hazus Program Generated	NSI 2022, Lightbox exterior wall type and construction year, California parcel data structure type. Open Street Map, USA Structures, and Skyscrapers.com building footprint height and number of stories.	All U.S.	None

[1]No income ratio data were available for the Pacific Territories (AS, GU, MP).

5.2 Building Characteristics

Building characteristics are an important component of the GBS. This section provides information regarding building characteristics used in Hazus such as number of buildings and other building attributes such as area, height and age.

5.2.1 Housing Units

The NSI 2022 dataset was used to populate housing unit values in Hazus 6.0. Information regarding the methodology and assumptions used by USACE in creating the NSI 2022 data can be found in the *NSI 2022 Technical Documentation* (USACE, 2022).

The evaluation of NSI 2022 showed notably high values for RES3F residential units in 13 states. To mitigate these erroneous values, a calibration factor derived from 2020 U.S. Census block data was developed and applied to each structure in all states in order to correct even small over or under assignments of units. The calibration factor was calculated for each Census block by first identifying the difference between the sum of the NSI 2022 residential units (RES1-RES3F) and the Census residential units, then subtracting this value from the sum of the NSI 2022 RES3 units (RES3A-F) and then dividing that total by the sum of the NSI residential units (RES1-RES3F). This calibration factor was then multiplied by the sum of the NSI 2022 residential units (RES1-RES3F) to calculate the new RES3 residential values rounded to the nearest whole number.

RES3 structures were then reclassified to ensure that the number of residential units matched their RES3A-F designation. Finally, the square footage of all RES3 units was compared to their corresponding values in the Hazus Study Region SQL table hzSqftFactors. If the square footage exceeded 3 times the hzSqftFactor value, then it was reassigned the maximum value of 3 times the hzSqftFactor value. Likewise, if the value was less than 3 times less than the average value, it was assigned the minimum value to reduce anomalies. Table 5-3 summarizes the values used for RES3 calibrations.

Table 5-2 hzSqftFactor Values used for RES3 Calibrations

Occupancy	Square Footage	3x Minimum Value	3x Maximum Value
RES3A	2,200	733	6,600
RES3B	4,400	1,467	13,200

Occupancy	Square Footage	3x Minimum Value	3x Maximum Value
RES3C	8,000	2,667	24,000
RES3D	15,000	5,000	45,000
RES3E	40,000	13,333	120,000
RES3F	80,000	26,667	240,000

5.2.2 Building Counts

Building counts were taken directly from NSI 2022 data where available, and from equivalent data in other areas (e.g., District of Columbia, Puerto Rico, U.S. Virgin Islands), then aggregated to the Census block-level. Information regarding the methodology and assumptions used by USACE in creating the NSI 2022 data can be found in the NSI 2022 Technical Documentation (USACE, 2022).

5.2.3 Building Area

For Hazus, building areas were taken directly from NSI 2022 data where available, and from equivalent data in other areas (e.g., District of Columbia, Puerto Rico, U.S. Virgin Islands), as noted in Table 3-19. The NSI 2022 method used parcel data records of square feet whenever available[1]. In the absence of this data, square footage was assigned from regional distributions that vary by occupancy type.

NSI 2022 estimates of square footage were based on building footprints when available. In the absence of parcel data and footprint data, square footage was estimated solely using the generic assumption regarding average square feet per employee. Square footage was kept between an established minimum and maximum range shown in Table 5-4. Information regarding the methodology and assumptions used by USACE in creating the NSI 2022 data can be found in the *NSI 2022 Technical Documentation* (USACE, 2022). In the Hazus 6.1 release, single-family home building areas in Texas were corrected reducing the statewide building area values by 6%.

Table 5-3 NSI 2022 Occupancy Type Areas

Occupancy Type	Average SqFt Per Unit or Employee[1]	Average SqFt Per Floor	Minimum SqFt	Maximum SqFt
RES1	1,500	1,500	500	5,000
RES2	1,000	1,500	500	2,000
RES3A	1,500	1,500	500	1,161,500
RES3B	750	1,500	500	1,161,500
RES3C	800	3,000	500	1,161,500
RES3D	750	5,000	500	1,161,500
RES3E	700	5,600	1,500	1,161,500
RES3F	650	5,200	1,500	1,161,500

[1] There was one anomalous RES1 square footage value for a single structure in Cherokee County, SC that was removed to reduce the overall RES1 Census Block square footage to a reasonable value. For more information and frequently asked questions regarding the NSI database, please visit https://www.hec.usace.army.mil/confluence/nsi/technicalreferences/latest/frequently-asked-questions.

Occupancy Type	Average SqFt Per Unit or Employee[1]	Average SqFt Per Floor	Minimum SqFt	Maximum SqFt
RES4	825	12,000	1,100	1,161,500
RES5	825	69,000	6,900	183,300
RES6	300	30,000	1,500	242,600
COM1	400	9,200	1,100	61,000
COM2	500	33,000	1,100	61,000
COM3	300	12,000	1,100	61,000
COM4	250	13,000	1,100	930,000
COM5	300	7,000	1,100	38,100
COM6	300	14,000	2,600	410,300
COM7	300	15,000	2,600	327,000
COM8	200	11,000	1,100	223,800
COM9	825	16,000	1,100	223,800
COM10	900	46,000	1,100	287,000
IND1	550	51,000	2,300	200,600
IND2	590	17,000	2,300	200,600
IND3	540	31,000	2,300	200,600
IND4	730	31,000	2,300	200,600
IND5	300	21,000	2,300	200,600
IND6	250	10,000	2,300	200,600
AGR1	250	10,000	1,100	200,600
REL1	300	10,000	1,100	235,300
GOV1	250	19,000	1,100	930,000
GOV2	250	7,000	1,100	31,600
EDU1	150	61,000	1,100	410,800
EDU2	300	66,000	1,100	196,200
NoMatch	500	20,000	1,100	930,000

[1]Note: The methodology for average square foot per unit or employee includes the summation of the number of employees, students, and institutionalized and nursing home population for the non-residential population.

5.2.4 Building Height

The NSI 2022 dataset was used to populate building height values in Hazus 6.0. Information regarding the methodology and assumptions used by USACE in creating the NSI 2022 data can be found in the NSI 2022 Technical Documentation (USACE, 2022). As noted in the NSI 2022 Technical Documentation, there is a known issue of structures reporting unrealistic number of stories when these values are estimated rather than provided from parcel data. This issue was addressed during the earthquake building type updates for Hazus 6.1 described in Section 5.5.1 below.

5.2.5 Building Age

The age of a building is important because the building codes (and the expected building performance) change over time. For example, with flooding hazards, development regulations change when a community enters the NFIP. The Census building age data are used to determine the percent of structures that were built before the community entered the NFIP and adopted the Flood Insurance Rate Map (FIRM). These initial maps, denoted as pre-FIRM data, with those issued afterwards being denoted as post-FIRM data. Building age data is used for all hazards to assist in establishing the hazard-specific mapping schemes as described later in this section. Significant updates for the earthquake mapping schemes with Hazus 6.1 leveraged construction year data where available from parcel data and used Census-derived median year built data where not available from parcel data.

At the block group level, Census data provides household counts by a range of years, typically decades, for construction. In assigning the age of buildings, the Hazus Methodology assumes that typical development practices result in the homogenous development of all blocks within a single block group. The median year of construction is used in the preparation of several key inventory attributes; however, during analysis, it is only used for flood depreciation losses.

For flood mapping schemes, including the estimates of pre- and post-FIRM percentages, Hazus assumes the same distribution of building age for all specific occupancies. In other words, the commercial/industrial development and the residential development throughout the block group are assumed to occur concurrently. Based on this assumption, the Census block group age is distributed throughout the constituent Census blocks relating to both residential and non-residential development. After completing this based on the most recent U.S. Census American Community Survey (ACS) 2020 data, a significant number of blocks and tracts with zero or unusual median year-built dates were identified that also had construction dates recorded by decade. In those cases, the construction dates by decade were used to compute a median year-built date.

The NSI 2022 dataset, which includes construction years obtained from parcel information, was used to update the NSI tsunami inventories as discussed in Section 5.8.

5.3 Garages

The NSI 2022 garage data were only sparsely populated, predominantly for non-residential structures. Table 5-5 shows the RES1 default percentages of garage type distributions.

Table 5-4 Distribution of Garage Types for Single-Family Residential Structures (% of total)

Census Region[1]	One-Car[2]	Two-Car	Three-Car	Carport	None
Northeast	29%	31%	5%	2%	33%
Midwest	21%	51%	9%	2%	17%
South[3]	14%	39%	4%	8%	35%
West	16%	51%	11%	6%	16%

5.4 All Hazards Mapping Scheme

As noted in Table 5-1 at the beginning of the section, all hazards use the same mapping scheme to link specific occupancy to general building type. The term “mapping scheme” in Hazus relates to the use of one or multiple lookup tables to link related data elements, such as specific occupancy with general building type. Starting with the Hazus 6.1 release, general building type mapping schemes are developed from site-specific NSI data and implemented at the tract level, whereas prior to Hazus 6.1, mapping schemes were at the state level. The general building type mapping schemes use the exterior wall type information where available in the NSI. Table 5-6 illustrates that this exterior wall type information is only available at a moderate rate across the country. Since no exterior wall type information was available for California, publicly available parcel data with structure type information were utilized as illustrated in Table 5-7. Where wall or structure type was not known, the original mapping schemes for the Western U.S. buildings (pre-1950, 1950-1970, and post-1970) based on information provided in the Earthquake Damage Evaluation Data for California publication by the Applied Technology Council (ATC-13, 1985) were used. Where parcel exterior wall types were unavailable elsewhere in the U.S., the original mapping schemes used are based on proprietary insurance data, knowledge of a limited number of experts, and inferences drawn from tax assessor’s records.

Table 5-5 Summary of Parcel Exterior Wall Type Attribution in the NSI 2022

State	Percent of NSI 2022 Structures with Parcel Exterior Wall Type
MA	90.2%
RI	89.7%
OK	89.5%
HI	88.4%
CT	86.9%
KS	84.8%
NV	84.7%
NE	84.2%
NH	84.1%
GA	83.5%
MT	82.8%
AL	82.7%
WY	81.0%
TN	79.2%
AZ	75.6%
OH	75.6%
FL	74.7%
DE	74.0%
NC	72.7%
CO	70.6%

State	Percent of NSI 2022 Structures with Parcel Exterior Wall Type
UT	69.7%
MS	69.3%
VA	69.0%
MD	64.5%
PA	63.7%
KY	63.0%
AR	61.0%
NY	59.5%
IA	58.1%
MN	55.1%
WA	54.8%
TX	53.7%
SC	51.6%
MO	51.5%
OR	51.4%
IL	45.1%
ME	43.2%
ID	42.6%
WV	39.5%
AK	36.0%
MI	32.3%
SD	25.7%
VT	19.0%
NJ	18.5%
NM	17.3%
WI	9.1%
LA	8.8%
ND	5.0%
IN	3.1%
CA	0.4%

Table 5-6 Summary of Percent of NSI 2022 Structures Attributed in GBS using County Parcel Construction Type

Geography	Percent of Structures with Parcel Construction Type
Los Angeles County	87%
Riverside County	86%
Sacramento County	86%
San Bernardino County	95%
San Diego County	90%
San Francisco County	83%
San Joaquin County	99.96%
Tehama County	99%
California	45%

For detailed tables with the general mapping scheme for all hazards, from specific occupancy to general building types, and the mapping schemes for earthquake specific building types, see Appendix A. With the release of Hazus 6.1, the earthquake specific building type schemes are now normalized by general building types rather than randomly distributed. As a result, when general building types were known (e.g. steel) only steel specific building types were assigned.

5.5 Other Earthquake Building Characteristics

5.5.1 Refining Number of Stories Attribution

Hazus 6.1 represents the first time that mid- and high-rise building types were assigned within earthquake building type mapping schemes by default. Previously, all buildings were mapped to low rise building types by default since reliable number of stories data were not available. The number of story data were also used to further refine Wood and Steel GBS assignments based on known number of story constraints described in Section 5.5.3. Due to the impact the number of stories attribute has in the Earthquake Model, an additional analysis to improve this attribute within the current release of the NSI was completed prior to the assignment of other earthquake building characteristics. These improvements were not implemented on the GBS, but rather used as intermediate inputs for the earthquake building characteristics. For this analysis, height and number of stories data was compiled from OpenStreetMap, FEMA's USA Structures, and SkyscraperPage.com.

A geospatial analysis was conducted to identify structures from each secondary data source building footprint that matched within a a 2 meter buffered radius of each NSI 2022 structure point. If no structures matched within a 2 meter buffer of an NSI 2022 structure point, this search radius was expanded to 5 meters. If a buffered NSI 2022 structure point matched with only one of the secondary data sources structures, then the NSI 2022 point was assigned the secondary data source's number of stories attributes. However, if there were multiple matches, the match was selected based on a prioritization of height, number of stories, and occupancy type. If an NSI structure point could not be corroborated or corrected based on secondary data sources, the structure's number of stories was considered unverified and considered low-rise. The process assigned each structure a verified number of stories from the most reliable dataset, noting any conditions present. SkyscraperPage.com data was considered the highest quality due to its community maintenance and accuracy in publicizing building stories. If SkyscraperPage.com data was consistent with NSI data within a slight buffer, it was used. Inconsistencies led to nuanced rules, where OSM data was preferred over skyscraper data if within the buffer. OSM data was also used over skyscraper data in certain cases of inconsistency, or if skyscraper data was too broad. NSI data was updated with USA Structures data in limited circumstances, primarily when the NSI data had out-of-range values. Table 5-8 describes the changes to the number of stories designation as low-, mid- and high-rise before and after the analysis.

Table 5-7 Summary of Reclassification of Number of Stories Grouping for Structures

Original NSI 2022 Structures Number of Stories Grouping	Final Structure Number of Stories Grouping	Number of Structures
Low-Rise	Low-Rise	116,966,310
Low-Rise	Mid-Rise	1,596,215
Low-Rise	New High	132,350
Mid-Rise	Low-Rise	1,057,668
Mid-Rise	Mid-Rise	90,575
Mid-Rise	New High	24,765
High-Rise	Low-Rise	355,493
High-Rise	Mid-Rise	6,719
High-Rise	New High	22,156
No Data	Low-Rise	1,403,574
No Data	Mid-Rise	4,360
No Data	New High	818

This analysis also revealed an additional issue within the NSI 2022 structure data in some state datasets (CA, FL and NY). The analysis showed that in many instances single skyscraper structure footprints matched with dozens to hundreds of NSI 2022 structures with the same building identification number (BID). In most cases, the NSI 2022 structures were a group of single-story RES1 (single-family) structures that had the same BID. Additional valid cases of multiple different types of occupancies for the same building footprint are also observed. Upon a review of Google Imagery, it was clear that these multiple RES1 records often represented single condos or mixed used buildings that were stacked as individual structures in the NSI 2022 data. Duplicated structures were flagged based on the BID and occupancy type as a “multi-BID” structure, with one structure of each occupancy type updated to represent all of the duplicate structures. For example, if within a BID there were 380 RES1 structures and 20 COM1 structures, all 400 records would be flagged as multi-unit records, with one RES3F (50+ units) and one COM1 record being flagged with building area and value summed to represent all their companion records with the same footprint. The remainder of the flagged “multi-BID” structures were filtered out of the data. This analysis resulted in the removal of 2,755,859 “multi-BID” structures from the intermediate data used for assigning earthquake building characteristics. Table 5-9 identifies the top 15 states impacted by this issue.

Table 5-8 Top 15 States with Multi-BID Structures

State	Total NSI 2022 Records	# Filtered Out (Multi-BID)*
CA	11,700,733	709,273
FL	8,371,305	668,015
NY	5,220,461	227,738
MI	4,351,753	124,484
MA	2,095,826	102,533
IL	4,449,599	93,309
MN	2,543,456	87,757
VA	2,928,607	75,318
TX	10,182,426	74,837
NV	1,133,908	66,810
CO	2,224,920	66,768
MD	2,126,519	65,001
GA	4,106,126	46,911
OH	4,912,910	36,578
WA	2,780,571	36,095

5.5.2 Seismic Design Level Designation

Three general approaches were implemented for estimating the seismic design level for each NSI 2022 structure point. One approach was used for structures constructed after the adoption of the International Building Code® (IBC) and International Residential Code® (IRC), which are referred to as IBC era construction for the purposes of this technical reference. The second approach was used for structures constructed under the Uniform Building Code (UBC) or earlier which are referred to as pre-IBC era construction for the purposes of this technical reference. The final approach was used for low earthquake risk jurisdictions.

These approaches all utilize the current effective S_{DS} and S_{D1} GIS contour data for states and territories, as provided by the USGS Survey in 2023. The S_{DS} and S_{D1} represent two-thirds of the site corrected short- and long-period ground motions, respectively, of the maximum considered earthquake (MCE). This data is derived from the S_{MS} and S_{M1} data incorporated into the 2020 NEHRP Recommended Seismic Provisions and the 2022 ASCE/SEI 7 Standard. Design ground motions are defined as a function of the (MCE) ground motions S_S and S_1, where S_S represents the MCE spectral acceleration in the short-period range for Site Class B, and S_1 represents the MCE spectral acceleration at the 1.0-second period for Site Class B (NEHRP Provisions, Sec. 4.1.2.4). The long period (1.0-second) ground motions are used in the classification of design level for mid- and high-rise structures in the IBC era, while the short period ground motions are used for low-rise building types. Site Classes are taken into account by applying soil factors to the MCE values. Site Class effects are considered through the use of $S_{MS} = F_a S_S$ for the short period, where F_a is the site coefficient, and $S_{M1} = F_v S_1$ for the long period, where F_v is the site coefficient. Site coefficients are elaborated on in the NEHRP Provisions, Sec. 4.1.2.4.

Design spectral accelerations (S_{DS} and S_{D1}) are obtained by multiplying SMS and S_{M1} by 2/3 – specifically, S_{DS} = (2/3) S_{MS} and S_{D1} = (2/3) S_{M1}.

5.5.2.1 IBC ERA CONSTRUCTION

In Hazus, the IBC era design levels are implemented for the construction years following the effective year of the IBC/IRC codes by a state or jurisdiction. FEMA's Building Codes Save: A Nationwide Study (BCS) (FEMA, 2020) and FEMA's Building Code Adoption Tracking (BCAT) Portal2 served as authoritative sources for the adoption of IBC/IRC codes. Table 5-10 and Table 5-11 summarize the relationship between the design levels and design ground motions for IBC/IRC adoption as published in Building Codes Save: A Nationwide Study (FEMA, 2020).

Table 5-9 Design Level Assignments for the IBC Code Series for Commercial Construction

Design Level	Low-Rise (Non-W1) Construction	Mid- and High-Rise Construction
Low Code	S_{DS} < 0.45	S_{D1} < 0.2
Moderate Code	0.45 ≤ S_{DS} < 0.9	0.2 ≤ S_{D1} < 0.4
High Code	0.9 ≤ S_{DS} < 1.4	0.4 ≤ S_{D1} < 0.8
Very High Code	1.4 ≤ S_{DS} < 1.75	0.8 ≤ S_{D1} < 1.15
Severe Code	S_{DS} ≥ 1.75	S_{D1} ≥ 1.15

Table 5-10 Design Level Assignments for One- and Two-Family Residential Construction for the IRC Code Series

Design Level	Conventional Constructions (Small W1,≤ 1,500 SF)	Engineered Construction (Large W1, >1,500 SF)
Low Code	S_{DS} < 0.5	S_{DS} < 0.45
Moderate Code	0.5 ≤ S_{DS} < 1.17	0.45 ≤ S_{DS} < 0.9
High Code	1.17 ≤ S_{DS} < 1.4	0.9 ≤ S_{DS} < 1.4
Very High Code	1.4 ≤ S_{DS} < 1.75	1.4 ≤ S_{DS} < 1.75
Severe Code	S_{DS} ≥ 1.75	S_{DS} ≥ 1.75

5.5.2.1.1 BCS STATES APPROACH

For six states (Alaska, California, Hawaii, Oregon, Utah and Washington), *Building Codes Save: A Nationwide Study* (FEMA, 2020) provides the recommended seismic design level at the 2010 census tract geography. *Building Codes Save: A Nationwide Study* (FEMA, 2020) performed an evaluation of design levels based on hazard mapping, site-corrections, and code adoption for each edition of the UBC and IBC/IRC closely coordinated with the USGS. The Commercial and Residential code adoption histories are compiled in Tables 6-3 and 6-4 in *Building Codes Save: A Nationwide Study* (FEMA, 2020). Appendix C provides a series of matrices for each studied state and noted jurisdiction identified in *Building Codes Save: A Nationwide Study* (FEMA, 2020) that identifies the benchmark adoption years.

[2] https://www.fema.gov/emergency-managers/risk-management/building-science/bcat

In Hazus, seismic design levels for 2020 census tracts are assigned based on the majority of the area of the 2020 intersecting with the 2010 census tract. This information is used as a lookup to provide design levels to NSI structures within the corresponding tract since *Building Codes Save: A Nationwide Study* (FEMA, 2020) lookups use 2010 census tract IDs.

5.5.2.1.2 BCAT STATES APPROACH

Outside the 6 states included in *Building Codes Save: A Nationwide Study* (FEMA, 2020), Hazus leverages data from FEMA's BCAT Portal to determine which other high seismic risk jurisdictions have adopted the latest building codes. High seismic risk jurisdictions are specifically defined in the BCAT based on the 2021 IBC and IRC ground motions and risk categories. The BCAT portal identifies jurisdictions as having "no Building Code Data" (Code 0), "Old or Weakened IBC/IRC, or No Code Adopted" (Code 1) or as "2018 or later IBC & IRC" (Code 2). The BCAT portal includes "Seismic Hazard Notes" for each jurisdiction where data is available, which provides additional information on jurisdictional weakening of seismic building codes. While this data provides the current building code adoption, the historic information is limited and does not identify the year the community first adopted the IBC code, which is required to determine the IBC design level using Tables F-10 and F-13 from *Building Codes Save: A Nationwide Study* (FEMA, 2020). Therefore, the adoption history from Reinhold (2020) was leveraged in conjunction with BCAT information for 14 high earthquake risk states. This adoption history is outlined in Table 5-12.

Table 5-11 Statewide Adoption Research Provided by Reinhold (2020)

State	1994 UBC Adoption	1997 UBC Adoption	First IBC Adoption Year	First IRC Adoption Year
Alabama	1997	2001	2008	2009
Arkansas	NA	NA	2003	2003
Georgia	NA	NA	2007	2007
Indiana	NA	1998	2003	2003
Kentucky	NA	NA	2002	2002
Maine	NA	NA	2004	2004
Montana	1996	1998	2002	2002
Mississippi	NA	NA	2011	2011
New Mexico	NA	1998	2004	2004
New York	NA	NA	2002	2002
North Carolina	NA	NA	2002	2001
Oklahoma	NA	NA	2012	2012
South Carolina	NA	NA	2002	2003
Texas	NA	NA	2006	2002
Vermont	NA	NA	2005	NA
Puerto Rico	NA	NA	2011	2011
Virgin Islands	NA	NA	2004	2004

For the BCAT high seismic risk jurisdictions, the following rules were used to assign seismic design level:

- BCAT Seismic Code 2: IBC/IRC code series design levels were applied starting with construction year 2003 (unless a different year for the start of the IBC era is indicated in the available Reinhold (2020) state history data) based on the assumption that these resistant jurisdictions began implementing IBC era construction practices at the beginning of the IBC era.

- BCAT Seismic Code 1 (Pre-2018 IBC Code currently adopted): Where the Building Code and Residential Code is an IBC/IRC era code and no weakening is described in Seismic Hazard notes within the BCAT Portal, IBC/IRC code series design levels were applied starting with construction year 2003 (unless a different year for the start of the IBC era is indicated in the available Reinhold (2020) state history data).

- BCAT Seismic Code 1 (with weakening): Where the Building Code and Residential Code is an IBC/IRC era code and weakening is described in Seismic Hazard notes, IBC/IRC code series design levels were applied starting with construction year 2003 (unless a different year for the start of the IBC era is indicated in the available Reinhold (2020) state history data). If weakening was described in the Seismic Hazard notes, then these design levels were downgraded one level. If the design level was already Low code then no downgrade was applied for IBC era construction. These downgrades will also apply to Essential Facility special codes where Very High was downgraded to High-Code-Special, High-Code-Special to Moderate-Code-Special and Moderate-Code-Special to Low-Code-Special. If the design level was already Low-Code-Special, then no downgrade was applied for IBC era construction.

- BCAT Seismic Code 0: No IBC era code design levels are applied.

Puerto Rico (PR), U.S. Virgin Islands (VI), American Samoa (AS), Northern Mariana Islands (MP), and Guam (GU) are all defined as high-risk jurisdictions by the BCAT. The following considerations were used for the territories:

- MP is BCAT Seismic Code 2 and follows the BCAT Seismic Code 2 rule outlined above.

- GU is BCAT Seismic Code 1 but is using a 2009 version of the IBC/IRC with weakening indicated and an assumed 2003 IBC/IRC entry date (construction year 2004 and later).

- AS uses a severely outdated building code and has no residential code. AS is based on UBC Zone 2A (MA 4), resulting in Pre-Code for all <1976, and Low Code for all 1976 to present.

- PR and VI are BCAT Seismic Code 2 and follow the BCAT Seismic Code 2 rule outlined above, utilizing the Reinhold (2020) adoption history for IBC of 2011 for PR and 2004 for VI.

Using the above rules and considerations, the construction year following the adoption of the first IBC or IRC code was applied to the IBC/IRC era design levels based on S_{DS} and S_{D1} outlined in tables F-10 and F-13 of *Building Codes Save: A Nationwide Study* (FEMA, 2020) (Table 5-10 and Table 5-11).

5.5.2.2 PRE IBC ERA CONSTRUCTION

For the six states covered in detail in *Building Codes Save: A Nationwide Study* (FEMA, 2020), a series of matrices for each state and noted jurisdictions were developed to implement design level assignments using the relationship between the adoption history, UBC seismic zone, the construction years and seismic design level. These matrices can be found in Appendix C.

For jurisdictions outside of the identified states in *Building Codes Save: A Nationwide Study* (FEMA, 2020) where S_{DS} 0.5g or greater or S_{D1} 0.2g or greater, the current Hazus approach for the Pre IBC era, based on 1997 UBC Zones (Figure 5-1) with some modification to dates based on the literature research was used. Table 5-13 outlines the relationship between the UBC seismic zone, construction year and seismic design level. Where UBC Seismic Zone is Zone 2A, Zone 1, or Zone 0, COM6, EDU1 and GOV2 structures are considered low code for construction years prior to 2003.

Table 5-12 Pre IBC Era Seismic Design Level based on UBC Seismic Zones and Construction Years for Non-BCS States

UBC Seismic Zone (NEHRP Map Area)	Pre-1976	1976 through 1995	1996 through First IBC/IRC Adoption Year*
Zone 4 (MA 7)	Pre-Code	Moderate-Code (MS for Essential Facilities (COM6, GOV2, EDU1))	High Code (HS for Essential Facilities (COM6, GOV2, EDU1))
Zone 3 (MA 6)	Pre-Code	Moderate-Code (MS for Essential Facilities (COM6, GOV2, EDU1))	Moderate-Code (MS for Essential Facilities (COM6, GOV2, EDU1))
Zone 2B (MA 5)	Pre-Code	Low-Code (LS for Essential Facilities (COM6, GOV2, EDU1))	Moderate-Code (MS for Essential Facilities (COM6, GOV2, EDU1))
Zone 2A (MA 4)	Pre-Code	Low Code	Low Code
Zone 1 (MA 2/3)	Pre-Code	Low Code	Low Code
Zone 0 (MA 1)	Pre-Code	Pre-Code	Low Code

**If no IBC/IRC adoption year has been identified then continue the design level through IBC era.*

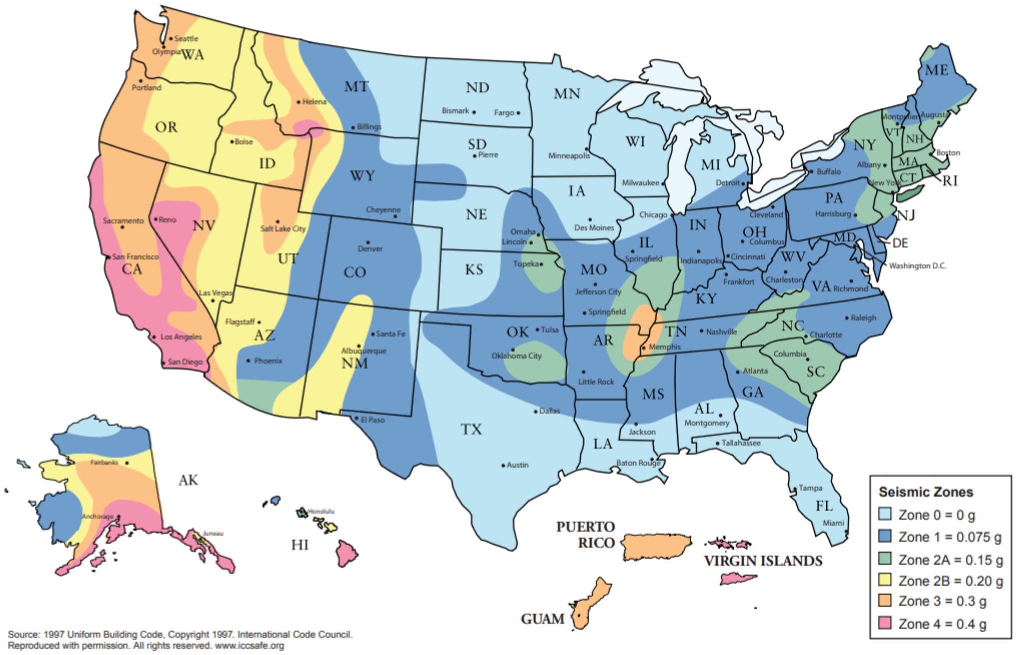


Figure 5-1 1997 UBC Zone Map

Based on current hazard data and BCAT documentation the following considerations were used to define the UBC seismic zones for MP and AS.

- MP is considered Zone 3 similar to Guam.
- AS is considered Zone 2A since it still uses the 1964 UBC and has no residential code.

5.5.2.3 LOW RISK JURISDICTIONS

For jurisdictions where S_{DS} < 0.5g and S_{D1} < 0.2g, the relationship between the UBC seismic zone, construction year and seismic design level in Table 5-14 is used. In Hazus, no structures built in 2003 (IBC-era) or later are assigned Pre-Code. Where UBC Seismic Zone is Zone 2A, Zone 1, or Zone 0, COM6, EDU1 and GOV2 structures are considered low code for construction years prior to 2003.

Table 5-13 Seismic Design Level based on UBC Seismic Zones and Construction Years for Low Risk Jurisdictions

UBC Seismic Zone (NEHRP Map Area)	Pre-1976	1976 through 2002	2003 through Present
Zone 2a/1 (MA 2,3,4)	Pre-Code	Low Code	Low Code (use LS for COM6, EDU1 and GOV2)
Zone 0 (MA 1)	Pre-Code	Pre-Code	Low Code (use LS for COM6, EDU1 and GOV2)

5.5.3 General Building Type Assignment

Hazus utilized NSI 2022 private attributes parcel exterior wall type and year built, and, for California, free publicly available parcel construction type data from 8 counties (Los Angeles, Riverside, Sacramento, San Bernardino, San Diego, San Francisco, San Joaquin, and Tehama) to improve the assignment general building types when data were available. Assessor and parcel data for all California counties were reviewed; however, only freely available, non-licensed public data were used. Table 5-15 provides a summary of the count of structures that were attributed. The Mid-West, East Coast and West Coast areas are defined in Table A-22 in Appendix A.

Table 5-14 Summary of Parcel Data used for the General Building Type and Earthquake Specific Building Type Assignment

Area	**Total NSI 2022 Structures (Count, in Millions)**	Year Built Attributed: Count (in Millions)	Year Built Attributed: Percentage	Exterior Wall/ Construction Type Attributed Count (in Millions)	Exterior Wall/ Construction Type Attributed Percentage
Mid-West	50.2	38.2	76%	25.7	51%
East Coast	47.4	39.5	83%	30.8	65%
West Coast	15.1	13.4	89%	9.6	63%
California	11.7	10.7	91%	5.3	45%

Special rules based on construction conventions were applied to translate the parcel exterior wall types and construction types to the appropriate Hazus general building type. For instance, structures constructed before 1976 in the west and exceeding 13 stories were assigned the general building type 'S' since only steel was allowed. In addition, structures exceeding 3 stories and built before 2015 or 5 stories and built after 2015 were not allowed to be wood. For structures lacking parcel data, building type mapping schemes were used. These mapping schemes are available in Appendix A.

5.5.4 Earthquake Specific Building Type

Similar to general building type assignment, where parcel data was available, earthquake-specific building types were directly assigned, and special case rules were implemented based on construction conventions. For example, structures with exterior wall types designated as metal, having three or fewer stories, and identified as occupancy types IND2, IND6, COM3, or AGR1 were assigned the earthquake-specific building type 'S3' to represent the steel building type typically used for these occupancies.

In cases where direct assignment of earthquake-specific building types was impossible, existing earthquake-specific building type mapping schemes were employed. These mapping schemes are available in Appendix A. Conversely to previous version of Hazus, this iteration considers the general building type and then assigns the earthquake specific building type based. For example, a structure must have a "S" general building type to be assigned a steel specific building type.

5.5.5 Other Mapping Schemes for the Earthquake Model

The only other mapping scheme for the Earthquake Model used in Hazus is earthquake specific building type to foundation type. Hazus assumes a shallow foundation as the default value for structures. More details on this assumption can be found in the *Hazus Earthquake Model Technical Manual* (FEMA, 2024).

5.6 Other Flood Building Characteristics

In Hazus, the only flood specific mapping scheme included is flood specific occupancy to foundation type, which ultimately leads to FFHAG based on foundation type. It is important to note that FFHAG is not synonymous with first floor elevation or lowest floor elevation. FFHAG is the assumed number of feet above the ground surface to the top of the finished floor. Flood GBS data requires information on year built relative to the NFIP community Entry Year to infer pre-FIRM and post-FIRM construction, which impacts FFHAG assumptions and, in conjunction with the number of stories, the selection of damage function used to estimate flood damages. For more information, see the *Hazus Flood Model Technical Manual* (FEMA, 2024).

5.6.1 Block Type Designation

Within the Flood Model, each Census block is designated as being subject to either Coastal (“C”), Riverine (“R”) or Great Lakes-type flooding (“L”). States with the potential for coastal flooding include Alabama, Alaska, California, Connecticut, Delaware, Florida, Georgia, Hawaii, Louisiana, Maine, Maryland, Massachusetts, Mississippi, New Hampshire, New Jersey, New York, North Carolina, Oregon, Pennsylvania, Rhode Island, South Carolina, Texas, Virginia and Washington. States with the potential for Great Lakes-type flooding include Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania and Wisconsin. The assignment of Block Type, and the associated assignment of NFIP entry date is used in the flSchemeMapping table in Hazus.

Table 5-16 describes input data and data source information used to create the Flood Model’s Block Type, stored in the Hazus flSchemeMapping table.

Table 5-15 Block Type Designation Input Data

Hazus 6.0 Dataset Name	Hazus 6.0 Dataset Date	Hazus 6.0 Dataset Source	Description of Hazus 6.0 Dataset	Geographic Coverage	Previous Data Source (Hazus 5.1)
hzCommunity_ Block	2022	Hazus Program Generated	Hazus Community Boundary Layer in Census blocks (see Section 3.4).	All U.S.	NFIP CIS data
National Flood Hazard Layer (NFHL)	2022	FEMA	NFHL dataset available for download from FEMA.	Coastal states, Great Lakes, PR and VI	Q3 data

Hazus 6.0 Dataset Name	Hazus 6.0 Dataset Date	Hazus 6.0 Dataset Source	Description of Hazus 6.0 Dataset	Geographic Coverage	Previous Data Source (Hazus 5.1)
Hazus Dasymetric and TIGER Census Blocks	2022	Hazus Program Generated	Hazus Census block feature class modified through processing as identified in Section 3.2.	Coastal states, Great Lakes, PR and VI	Census block feature class
Hazus Shoreline	2022	Hazus Program Generated	Shoreline feature class provided in Hazus 5.1 for coastal flood analysis.	Coastal states, Great Lakes, PR and VI	Hazus shoreline
USGS HUC-8	May 2022	USGS	Watershed Boundary Dataset contains the Hydrologic Units by Hydrologic Unit Code.	All U.S.	National Hydrography Dataset 2014
NFIP Community Status Information	2022	FEMA	NFIP Community Status Book.	All U.S.	NFIP Community Status Book 2014

The methodology to identify and attribute the coastal Census Block Type field selected any Census block (dasymetric from Hazus) that intersects any of the following areas:

- Buffered coastal flood zones from the NFHL (buffer distances and flood zones identified in Table 5-17).
- Buffered Hazus coastline (buffer = 0.5 miles).
- Buffered areas of NFHL flood zones designated “OPEN WATER” (buffer=0.5 miles).

Within the NFHL there are several combinations of the flood zone with flood zone subtype. The various combinations, including the buffer distance, are listed in Table 5-17.

Table 5-16 Combinations of NFHL Flood Zone and Flood Zone Subtype Considered Coastal

Coastal V (Buffer = 2,000 feet)
V
V, COASTAL FLOODPLAIN
VE
VE, COASTAL FLOODPLAIN
VE, RIVERINE FLOODWAY SHOWN IN COASTAL ZONE

Coastal A (Buffer = 500 feet)
A, COASTAL FLOODPLAIN
AE, COASTAL FLOODPLAIN
AE, COMBINED RIVERINE AND COASTAL FLOODPLAIN
AE, RIVERINE FLOODWAY IN COMBINED RIVERINE AND COASTAL ZONE
AE, RIVERINE FLOODWAY SHOWN IN COASTAL ZONE
AO, COASTAL FLOODPLAIN

The methodology used to identify and attribute Great Lakes shoreline Census Block Type was as follows:

- The HUC-8 watershed boundaries for each of the five Great Lakes was used as the coastal designator with a 0.5-mile buffer applied to that shoreline. The HUC-8 boundaries were used because the Hazus shoreline was not isolated to the lakes themselves and also included the rivers that connected each Great Lake. Since these rivers were not a part of the Great Lakes, and therefore would not produce Great Lake type coastal flooding events, it was determined that the analysis should only focus on the Great Lakes shoreline instead.
- As with the coastal blocks, two NFHL buffers was added to better encompass the shoreline blocks. The NFHL areas used were selected by intersecting the NFHL polygons and the HUC-8 Great Lakes polygons, then removing all polygons within the NFHL that were not located within the Special Flood Hazard Area (SFHA), limiting areas to within the regulatory floodplain. This process also removed polygons not associated with stillwater areas. A buffer was then applied to the Zone As and Zone Vs as described in Table 5-17.

The coastal and Great Lake shoreline approach required several manual exceptions as listed in Table 5-18.

Table 5-17 Coastal and Great Lake Shoreline Approach - Manual Exceptions

State	Manual Exception
California	Selection of coastal blocks in California included an additional 500-foot buffer on AE zones with a Static Base Flood Elevation (BFE) greater than -5 feet and less than or equal to 8 feet. The 8 feet criteria was used primarily to deal with stillwater areas at the confluence of the Sacramento and San Joaquin Rivers.
Florida	▪ Lake Okeechobee in FL was manually reset to “R” because it’s not a Great Lake, and while there are waves on Lake Okeechobee, it is surrounded by dikes which are not expected to be developed. Because it has been assumed that the "Lakes" designation is intended to apply specifically to the Great Lakes, Lake Okeechobee was reset to “R”. ▪ Monroe County, FL used a 1-mile coastline buffer because the Hazus shoreline is generalized and does not adequately delineate the island boundaries.
Georgia	Islands statewide in Georgia are wide (front to back), not typical barrier islands – these are sea islands. For selected Counties (Bryan County, Camden County, Chatham County, Glynn County, Liberty County, and McIntosh County), the 1-mile coastline buffer was used.

State	Manual Exception
Michigan	▪ The AE Zone for Lake Charlevoix was offset from the Lake HUC-8, missing the selection criteria, so the lake Zone AE with a buffer of 500 feet was added in manually. ▪ The coastline for Lake St. Clair was added and buffered by 0.5-miles. The coastline used was the Hazus coastline since the HUC-8 extended too far outside the lake boundary.
New Jersey	In Middlesex County, the "Open Water" buffer includes an erroneous land-locked sliver; the Census blocks comprising the sliver were manually reset to "R."
South Carolina	Islands in southern South Carolina are wide (front to back), not typical barrier islands – these are sea islands. For selected Counties in South Carolina (Beaufort County, Charleston County, Colleton County, and Jasper County), the 1-mile coastline buffer was used.
Virginia	In the Virginia tidewater areas, the 0.5-mile coastline buffer is insufficient because the area is very flat; selected Counties (Hampton County, Newport News County, Poquoson County, and York County) used the 1-mile coastline buffer.

The identification of the coastal or lake Block Type had several limitations due to coastline or flood data limitations as described in Table 5-19.

Table 5-18 Census Block Type Data Limitations

State	Limitations
Alaska	There are no flood hazard maps in Ketchikan, and the coastline doesn't adequately capture the associated waterway, so coastal blocks are not identified in the vicinity of the unmapped waterway.
Delaware/ Maryland	The NFHL flood zones were used to identify coastal blocks since the Hazus coastline does not always directly follow the coast. While improving the analysis a few gaps were still identified due to an imprecise shoreline and a lack of mapped flood hazard zones. The including the following areas: Cape Windsor, inland of Fenwick Island, in the unincorporated areas of Sussex Co, DE and Worchester, MD where the coastline does not follow the bay behind Ocean City. In Worchester the addition of the open water buffer did improve the coastal identification.
Illinois	With the addition of the flood zones along the lake shore, the lake coastal designation extends further inland within Chicago than in the previous version.
Minnesota	There is a gap in the NFHL data within the city of Duluth on the MN side of the WI/MN county line, however the WI flood zones do capture part of the lake coast blocks along the St. Louis River.
New York/ New Jersey	On the inland side of Staten Island, neither the coastal flood data nor the coastline picked up the Arthur Kill waterway. On the east side of Manhattan, the coastline does not follow the East River, and there is no coastal flood data. These areas are not identified as coastal.
Oregon	Siletz Bay, Yaquina Bay in Lincoln County, and Coos Bay in Coos County are not represented in the NFHL as having Open Water areas, but are mapped as AE, where a portion is a static BFE and a portion is not. Since the flood hazard maps do not have Open Water or V zones, these areas are not flagged as coastal blocks.

State	Limitations
Puerto Rico	The two bays to the east of San Juan (Laguna San Jose and Laguna La Torrecilla) are not labeled as coastal since they are A Zones with low static BFE. Some of these flood zones are not labeled with a coastal label and would likely be coastal using a manual setting.
South Carolina	The coastline near Charleston does not capture the Mt. Pleasant area east of Charleston (the mainland) because the coastline follows the barrier island coast only. As noted in Table 5-8, an exception to the processing rule (1-mile coastline buffer instead of 0.5-mile) is applied to help address this issue.
Texas	▪ Port Arthur and Beaumont, Jefferson County, TX, were not identified to have Coastal Census blocks because of the lack of NFHL data. Also, the shoreline does not follow the Sabine River, so a coastline buffer was not able to identify it either. ▪ Within Corpus Christi, TX there is no NFHL data and the coastline does not follow Corpus Christi Bay.
Virginia/DC/ Maryland	A limit of V zones differs from limit of tidal influence in City of Alexandria, VA; County of Arlington, VA; Fairfax County, VA; Prince George's County, MD and Washington, DC. This means that there are no coastal blocks in these areas, despite being tidally influenced. Coastal Census blocks are therefore only identified in areas in the vicinity of the Hazus shoreline. A similar issue occurred in Baltimore MD, where the coastline does not adequately reflect the boundaries of the inner harbor, effectively missing several backwater areas. The addition of the open water buffer improved this.

The flSchemeMapping layer was developed by starting with the hzCommunity_Block layer (Section 3.4) comprised of duplicate blocks (if the blocks were located within a Tribal or SLUA boundary) and attributing the blocks with percentages based on how much of the block resided within each jurisdiction. The Census block was assigned the CID of the jurisdiction with the largest percentage of Census block's geographic area. However, along the outer edges of the Tribal and SLUA communities, where there were no other neighboring communities, the percentages of the Tribal or SLUA communities within each Census block was generally low, catching only slivers. The flSchemeMapping layer was created using the fields described in Table 5-20.

Table 5-19 flSchemeMapping Layer Field Descriptions

Field Name	Description
CensusBloc	The Census blocks used were the same ones used while compiling the hzCommunity_Block layer. However, since the hzCommunity_Block layer contains duplications where Tribal lands and SLUAs overlap, they were reduced to single instances of each block.
SchemeId	Scheme ID is a concatenation of State Abbreviation, BlockType and "0001". The State Abbreviation is derived from the first two digits of the Census block number. The Block Type is R, C, or L and is described previously in this section.
EntryDate	The Entry Date is taken from the NFIP Community Status Information. The Entry Date was assigned by selecting the earliest of the three tabulated dates: Emergency Program Start Date, Flood Hazard Boundary Map (FHBM) Start Date, or Regular Program Entry Date. This means a community, for the purpose of applying post-FIRM Hazus riverine and coastal mapping schemes, begins to see a potential reduction in losses based on the earliest date rather than the final regular program Entry Date. Communities that have not yet entered the regular program also may have post-FIRM schemes applied. The approach reflects the assumption that activities to help mitigate flood losses in the flood hazard areas are occurring before the regular program Entry Date. These Entry Dates were then combined with the Area_ID numbers in the hzCommunty_Block layer to attach an Entry Date for each community within the hzCommunity_Block layer. Since a Census block could fall within both a Jurisdiction and Tribal area, or within a Jurisdiction and a SLUA, the process of determining which Entry Date was assigned included: ▪ For non-overlapping Census blocks, the Jurisdiction Entry Date was chosen. If the date was NULL or 0, a "0" was input into the EntryDate Column. ▪ For overlapping Census blocks, if the percentage of the Tribal or SLUA blocks was <50%, then the Jurisdiction Entry Date was chosen. ▪ If the Tribal or SLUA was ≥ 50%, but did not have a CID, then the Jurisdiction was chosen. ▪ If the Tribal or SLUA was ≥ 50%, and did have a CID, then the Tribal or SLUA date was chosen.

5.6.2 Building Year Built and Pre-FIRM/Post-FIRM Designation

The U.S. Congress established the NFIP with the passage of the National Flood Insurance Act of 1968. Therefore, all buildings built before the community entered the NFIP are designated as pre-FIRM. Post-FIRM designations are based on the year the community (viewed by Census block in the Flood Specific Occupancy Mapping) started participating in the NFIP. Users can edit the entry date and modify pre-FIRM/post-FIRM designations.

In the baseline GBS, the percent of pre-FIRM and post-FIRM buildings in each Census block is estimated during the flood loss analysis using household counts built by decade (pre-1940, 1940-1949, 1950-1959, 1960-1969, 1970-1979, 1980-1989, 1990-1999, 2000-2009, 2010-2013, post-2013) from Census data and the date of community entry into the NFIP. For the decade in which the community entered the NFIP, buildings are entirely distributed to post-FIRM. Non-residential buildings were not included in the previously described counts. An NFIP entry date after 2013 will result in a post-FIRM percentage based on the households in the post-2013 range.

Additionally, users should note that customizations of pre- and post-FIRM distributions will not result in a substantial change in losses in riverine flood zones due to a lack of substantive differences between default pre-FIRM and post-FIRM mapping schemes as shown in Table 5-17. Customization of pre- and post-FIRM mapping schemes can be completed by users, however, due to current limitations in the graphical user interface it is recommended that interested users contact the Hazus Help Desk (see Section 1.5).

5.6.3 Flood Foundation Types

The distribution of Flood Specific Occupancy Mapping foundations, the associated FFHAGs, and the pre/post-FIRM relationships are the controlling parameters affecting flood damage within the model. The Flood Model allows the user to define or control these parameters in the Flood Specific Occupancy Mapping dialogs. The FFHAG dialogs are not functional in Hazus 6.0. This section will focus on the process by which the foundation distributions and the first-floor heights above grade are defined.

To optimize processing, GBS distribution tables that contain the percentages of both pre- and post-FIRM foundation type distributions are incorporated into Study Regions during aggregation. These are provided for Riverine, Coastal and Lake distribution schemes for every State. The distributions include Block Type (Riverine, Coastal, or Lake), specific occupancy, number of stories or split level, pre- or post-FIRM, Foundation Types, and, in the case of Coastal schemes, the distributions within Coastal A and V zones are provided. Also, for non-residential specific occupancies, the building age data is a data field used to assign unique values as provided in the precompiled flood mapping schemes (see Table 5-17).

Some additional considerations for these assignments:

- Mapping schemes are provided for pre- and post-FIRM development and applied at the Census block based on the community's entry date into the NFIP as reported in the Community Status Book (see Section 5.6.1). With the pre- and post-FIRM assignments, Hazus treats the entire Study Region as if SFHA regulations are in effect, not just areas designated on a community's FIRM.
- Block Type assignments (see Section 5.6.1) assume "R" riverine unless within a "C" coastal region or "L" Great Lakes, for Census blocks that are immediately adjacent to the Great Lakes. For those Census blocks with both riverine and coastal hazards, it is assumed that the coastal foundation practices will dominate, since the building codes for coastal hazards are more stringent, so these blocks are coded as "C" (coastal) or "L" (lake). This Block Type assignment determines the foundation types and FFHAG described in this section.

To develop a distribution of foundation types, the following foundation definitions are used:

- *Pile:* An open foundation, composed of tall and slender members, embedded deeply into the ground. A pile is a single element, not built-up on site like a pier. Cast-in-place columns supported by a deep foundation (pile cap, mat, or raft below the anticipated scour depth) are classified as a pile foundation. In some pile-supported buildings, shear walls may be used to transfer shear from the upper building to the embedded foundation elements.

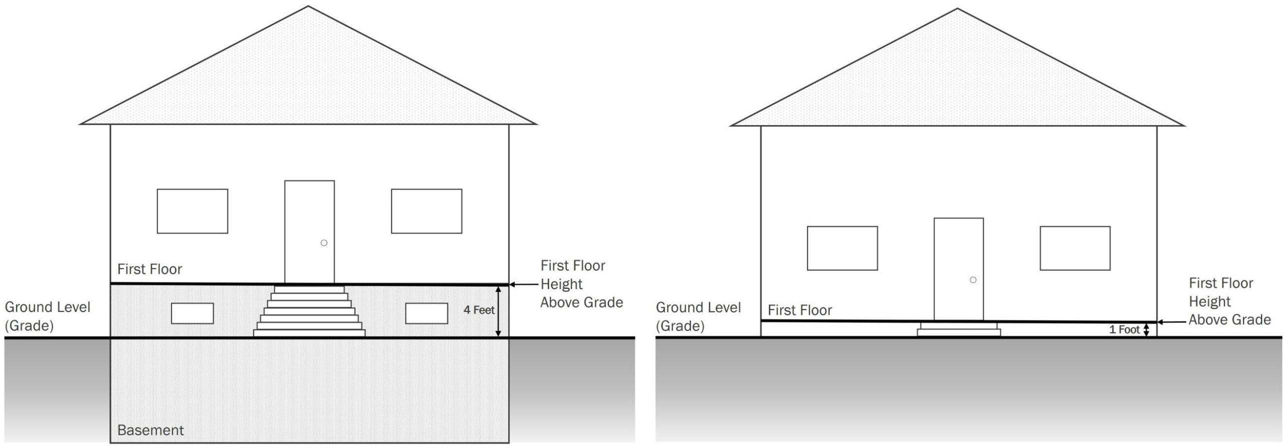
- *Pier:* An open foundation (no load-bearing perimeter walls) usually built of masonry units and supported by shallow footings. Piers usually range from approximately 2 feet to 8 feet in height.
- *Solid Wall:* Load-bearing perimeter walls greater than 4 feet in height, usually supported by shallow footings. Floor beams or joists usually rest atop the walls and may or may not be supported by interior piers or columns.
- *Basement or Garden-Level Basement:* Any level or story with its floor subgrade on all sides. Usually load bearing, masonry or concrete walls around the perimeter of the building, supported on shallow footings. Floor beams or joists rest atop the walls. Shallow basements with windows slightly above grade are defined as a garden level basement.
- *Crawlspace:* Usually short (less than 4 feet high), load bearing, masonry or concrete walls around the perimeter of the building footprint, supported on shallow footings. Floor beams or joists rest atop the walls and may also rest on interior piers.
- *Fill:* Soil built up above the natural ground elevation and used to support a slab or shallow footings.
- *Slab-on-Grade:* Concrete slab resting on the ground. It may have its edges thickened or turned down but does not rely on other walls or footings for support.

The Hazus Flood Model further classifies RES3 and non-residential categories into types by NUM_STORIES, however, there are not unique flood depth damage functions for those types. Rules can be developed to help reduce anomalies potentially based on other data sources such as land use, Census urban areas, or limits that can be established based on occupancy type.

Contact the Hazus Help Desk (see Section 1.5) for guidance on best practices to customize General Building Stock source data related to mapping schemes within a Study Region.

5.6.3.1 FIRST FLOOR HEIGHT ABOVE GRADE

Figure 5-2 shows two examples: FFHAG for a structure with basement, and FFHAG for a structure with a slab foundation. The default FFHAG values set for the entire United States are shown in Table 5-21. The default FFHAG values are read-only. There are 168 combinations that yield 56 unique FFHAG IDs. Contact the Hazus Help Desk (see Section 1.5) for guidance on best practices to customize specific variables related to FFHAG values.



Structure with Basement | Structure on Slab

Figure 5-2 First Floor Height Above Grade for Structure with Basement and Structure on Slab

Table 5-20 Default First Floor Height Above Grade Set

ID	FIRM	Block Type	Zone	Foundation	Basement	First Floor Height (ft.)
1	Pre-	Riverine[1]	Zone A Coastal	Pile	N	7
1	Pre-	Riverine[1]	Zone CA Coastal	Pile	N	7
1	Pre-	Riverine[1]	Riverine	Pile	N	7
1	Pre-	Riverine[1]	Zone V Coastal	Pile	N	7
2	Pre-	Riverine[1]	Zone A Coastal	Pier	N	5
2	Pre-	Riverine[1]	Zone CA Coastal	Pier	N	5
2	Pre-	Riverine[1]	Riverine	Pier	N	5
2	Pre-	Riverine[1]	Zone V Coastal	Pier	N	5
3	Pre-	Riverine[1]	Zone A Coastal	Solid Wall	N	7
3	Pre-	Riverine[1]	Zone CA Coastal	Solid Wall	N	7
3	Pre-	Riverine[1]	Riverine	Solid Wall	N	7
3	Pre-	Riverine[1]	Zone V Coastal	Solid Wall	N	7
4	Pre-	Riverine[1]	Zone A Coastal	Basement/Garden	B	4
4	Pre-	Riverine[1]	Zone CA Coastal	Basement/Garden	B	4
4	Pre-	Riverine[1]	Riverine	Basement/Garden	B	4
4	Pre-	Riverine[1]	Zone V Coastal	Basement/Garden	B	4
5	Pre-	Riverine[1]	Zone A Coastal	Crawl Space	N	3
5	Pre-	Riverine[1]	Zone CA Coastal	Crawl Space	N	3
5	Pre-	Riverine[1]	Riverine	Crawl Space	N	3
5	Pre-	Riverine[1]	Zone V Coastal	Crawl Space	N	3
6	Pre-	Riverine[1]	Zone A Coastal	Fill	N	2

ID	FIRM	Block Type	Zone	Foundation	Basement	First Floor Height (ft.)
6	Pre-	Riverine[1]	Zone CA Coastal	Fill	N	2
6	Pre-	Riverine[1]	Riverine	Fill	N	2
6	Pre-	Riverine[1]	Zone V Coastal	Fill	N	2
7	Pre-	Riverine[1]	Zone A Coastal	Slab on Grade	N	1
7	Pre-	Riverine[1]	Zone CA Coastal	Slab on Grade	N	1
7	Pre-	Riverine[1]	Riverine	Slab on Grade	N	1
7	Pre-	Riverine[1]	Zone V Coastal	Slab on Grade	N	1
8	Post-	Riverine[2]	Zone A Coastal	Pile	N	8
8	Post-	Riverine[2]	Zone CA Coastal	Pile	N	8
8	Post-	Riverine[2]	Riverine	Pile	N	8
8	Post-	Riverine[2]	Zone V Coastal	Pile	N	8
9	Post-	Riverine[2]	Zone A Coastal	Pier	N	6
9	Post-	Riverine[2]	Zone CA Coastal	Pier	N	6
9	Post-	Riverine[2]	Riverine	Pier	N	6
9	Post-	Riverine[2]	Zone V Coastal	Pier	N	6
10	Post-	Riverine[2]	Zone A Coastal	Solid Wall	N	8
10	Post-	Riverine[2]	Zone CA Coastal	Solid Wall	N	8
10	Post-	Riverine[2]	Riverine	Solid Wall	N	8
10	Post-	Riverine[2]	Zone V Coastal	Solid Wall	N	8
11	Post-	Riverine[2]	Zone A Coastal	Basement/Garden	B	4
11	Post-	Riverine[2]	Zone CA Coastal	Basement/Garden	B	4
11	Post-	Riverine[2]	Riverine	Basement/Garden	B	4
11	Post-	Riverine[2]	Zone V Coastal	Basement/Garden	B	4
12	Post-	Riverine[2]	Zone A Coastal	Crawl Space	N	4
12	Post-	Riverine[2]	Zone CA Coastal	Crawl Space	N	4
12	Post-	Riverine[2]	Riverine	Crawl Space	N	4
12	Post-	Riverine[2]	Zone V Coastal	Crawl Space	N	4
13	Post-	Riverine[2]	Zone A Coastal	Fill	N	2
13	Post-	Riverine[2]	Zone CA Coastal	Fill	N	2
13	Post-	Riverine[2]	Riverine	Fill	N	2
13	Post-	Riverine[2]	Zone V Coastal	Fill	N	2
14	Post-	Riverine[2]	Zone A Coastal	Slab on Grade	N	1
14	Post-	Riverine[2]	Zone CA Coastal	Slab on Grade	N	1
14	Post-	Riverine[2]	Riverine	Slab on Grade	N	1
14	Post-	Riverine[2]	Zone V Coastal	Slab on Grade	N	1

ID	FIRM	Block Type	Zone	Foundation	Basement	First Floor Height (ft.)
15	Pre-	Coastal[3]	Zone A Coastal	Pile	N	7
15	Pre-	Coastal[3]	Zone CA Coastal	Pile	N	7
15	Pre-	Coastal[3]	Riverine	Pile	N	7
15	Pre-	Coastal[3]	Zone V Coastal	Pile	N	7
16	Pre-	Coastal[3]	Zone A Coastal	Pier	N	5
16	Pre-	Coastal[3]	Zone CA Coastal	Pier	N	5
16	Pre-	Coastal[3]	Riverine	Pier	N	5
16	Pre-	Coastal[3]	Zone V Coastal	Pier	N	5
17	Pre-	Coastal[3]	Zone A Coastal	Solid Wall	N	7
17	Pre-	Coastal[3]	Zone CA Coastal	Solid Wall	N	7
17	Pre-	Coastal[3]	Riverine	Solid Wall	N	7
17	Pre-	Coastal[3]	Zone V Coastal	Solid Wall	N	7
18	Pre-	Coastal[3]	Zone A Coastal	Basement/Garden	B	4
18	Pre-	Coastal[3]	Zone CA Coastal	Basement/Garden	B	4
18	Pre-	Coastal[3]	Riverine	Basement/Garden	B	4
18	Pre-	Coastal[3]	Zone V Coastal	Basement/Garden	B	4
19	Pre-	Coastal[3]	Zone A Coastal	Crawl Space	N	3
19	Pre-	Coastal[3]	Zone CA Coastal	Crawl Space	N	3
19	Pre-	Coastal[3]	Riverine	Crawl Space	N	3
19	Pre-	Coastal[3]	Zone V Coastal	Crawl Space	N	3
20	Pre-	Coastal[3]	Zone A Coastal	Fill	N	2
20	Pre-	Coastal[3]	Zone CA Coastal	Fill	N	2
20	Pre-	Coastal[3]	Riverine	Fill	N	2
20	Pre-	Coastal[3]	Zone V Coastal	Fill	N	2
21	Pre-	Coastal[3]	Zone A Coastal	Slab on Grade	N	1
21	Pre-	Coastal[3]	Zone CA Coastal	Slab on Grade	N	1
21	Pre-	Coastal[3]	Riverine	Slab on Grade	N	1
21	Pre-	Coastal[3]	Zone V Coastal	Slab on Grade	N	1
22	Post-	Coastal[4]	Zone A Coastal	Pile	N	8
22	Post-	Coastal[4]	Zone CA Coastal	Pile	N	8
22	Post-	Coastal[4]	Riverine	Pile	N	8
22	Post-	Coastal[4]	Zone A Coastal	Pier	N	6
23	Post-	Coastal[4]	Zone CA Coastal	Pier	N	6
23	Post-	Coastal[4]	Riverine	Pier	N	6
23	Post-	Coastal[4]	Zone A Coastal	Solid Wall	N	8

ID	FIRM	Block Type	Zone	Foundation	Basement	First Floor Height (ft.)
23	Post-	Coastal[4]	Zone CA Coastal	Solid Wall	N	8
24	Post-	Coastal[4]	Riverine	Solid Wall	N	8
24	Post-	Coastal[4]	Zone A Coastal	Basement/Garden	B	4
24	Post-	Coastal[4]	Zone CA Coastal	Basement/Garden	B	4
24	Post-	Coastal[4]	Riverine	Basement/Garden	B	4
25	Post-	Coastal[4]	Zone A Coastal	Crawl Space	N	4
25	Post-	Coastal[4]	Zone CA Coastal	Crawl Space	N	4
25	Post-	Coastal[4]	Riverine	Crawl Space	N	4
25	Post-	Coastal[4]	Zone A Coastal	Fill	N	2
26	Post-	Coastal[4]	Zone CA Coastal	Fill	N	2
26	Post-	Coastal[4]	Riverine	Fill	N	2
26	Post-	Coastal[4]	Zone A Coastal	Slab on Grade	N	1
26	Post-	Coastal[4]	Zone CA Coastal	Slab on Grade	N	1
27	Post-	Coastal[4]	Riverine	Slab on Grade	N	1
27	Post-	Coastal[4]	Zone A Coastal	Pile	N	8
27	Post-	Coastal[4]	Zone CA Coastal	Pile	N	8
27	Post-	Coastal[4]	Riverine	Pile	N	8
28	Post-	Coastal[4]	Zone A Coastal	Pier	N	6
28	Post-	Coastal[4]	Zone CA Coastal	Pier	N	6
28	Post-	Coastal[4]	Riverine	Pier	N	6
28	Post-	Coastal[4]	Zone A Coastal	Solid Wall	N	8
29	Post-	Coastal[5]	Zone V Coastal	Pile	N	8
30	Post-	Coastal[5]	Zone V Coastal	Pier	N	8
31	Post-	Coastal[5]	Zone V Coastal	Solid Wall	N	8
32	Post-	Coastal[5]	Zone V Coastal	Basement/Garden	B	4
33	Post-	Coastal[5]	Zone V Coastal	Crawl Space	N	4
34	Post-	Coastal[5]	Zone V Coastal	Fill	N	2
35	Post-	Coastal[5]	Zone V Coastal	Slab on Grade	N	1
36	Pre-	Lake[6]	Zone A Coastal	Pile	N	7
36	Pre-	Lake[6]	Zone CA Coastal	Pile	N	7
36	Pre-	Lake[6]	Riverine	Pile	N	7
36	Pre-	Lake[6]	Zone V Coastal	Pile	N	7
37	Pre-	Lake[6]	Zone A Coastal	Pier	N	5
37	Pre-	Lake[6]	Zone CA Coastal	Pier	N	5
37	Pre-	Lake[6]	Riverine	Pier	N	5

ID	FIRM	Block Type	Zone	Foundation	Basement	First Floor Height (ft.)
37	Pre-	Lake[6]	Zone V Coastal	Pier	N	5
38	Pre-	Lake[6]	Zone A Coastal	Solid Wall	N	7
38	Pre-	Lake[6]	Zone CA Coastal	Solid Wall	N	7
38	Pre-	Lake[6]	Riverine	Solid Wall	N	7
38	Pre-	Lake[6]	Zone V Coastal	Solid Wall	N	7
39	Pre-	Lake[6]	Zone A Coastal	Basement/Garden	B	4
39	Pre-	Lake[6]	Zone CA Coastal	Basement/Garden	B	4
39	Pre-	Lake[6]	Riverine	Basement/Garden	B	4
39	Pre-	Lake[6]	Zone V Coastal	Basement/Garden	B	4
40	Pre-	Lake[6]	Zone A Coastal	Crawl Space	N	3
40	Pre-	Lake[6]	Zone CA Coastal	Crawl Space	N	3
40	Pre-	Lake[6]	Riverine	Crawl Space	N	3
40	Pre-	Lake[6]	Zone V Coastal	Crawl Space	N	3
41	Pre-	Lake[6]	Zone A Coastal	Fill	N	2
41	Pre-	Lake[6]	Zone CA Coastal	Fill	N	2
41	Pre-	Lake[6]	Riverine	Fill	N	2
41	Pre-	Lake[6]	Zone V Coastal	Fill	N	2
42	Pre-	Lake[6]	Zone A Coastal	Slab on Grade	N	1
42	Pre-	Lake[6]	Zone CA Coastal	Slab on Grade	N	1
42	Pre-	Lake[6]	Riverine	Slab on Grade	N	1
42	Pre-	Lake[6]	Zone V Coastal	Slab on Grade	N	1
43	Post-	Lake[7]	Zone A Coastal	Pile	N	8
43	Post-	Lake[7]	Zone CA Coastal	Pile	N	8
43	Post-	Lake[7]	Riverine	Pile	N	8
44	Post-	Lake[7]	Zone A Coastal	Pier	N	6
44	Post-	Lake[7]	Zone CA Coastal	Pier	N	6
44	Post-	Lake[7]	Riverine	Pier	N	6
45	Post-	Lake[7]	Zone A Coastal	Solid Wall	N	8
45	Post-	Lake[7]	Zone CA Coastal	Solid Wall	N	8
45	Post-	Lake[7]	Riverine	Solid Wall	N	8
46	Post-	Lake[7]	Zone A Coastal	Basement/Garden	B	4
46	Post-	Lake[7]	Zone CA Coastal	Basement/Garden	B	4
46	Post-	Lake[7]	Riverine	Basement/Garden	B	4
47	Post-	Lake[7]	Zone A Coastal	Crawl Space	N	4
47	Post-	Lake[7]	Zone CA Coastal	Crawl Space	N	4

ID	FIRM	Block Type	Zone	Foundation	Basement	First Floor Height (ft.)
47	Post-	Lake[7]	Riverine	Crawl Space	N	4
48	Post-	Lake[7]	Zone A Coastal	Fill	N	2
48	Post-	Lake[7]	Zone CA Coastal	Fill	N	2
48	Post-	Lake[7]	Riverine	Fill	N	2
49	Post-	Lake[7]	Zone A Coastal	Slab on Grade	N	1
49	Post-	Lake[7]	Zone CA Coastal	Slab on Grade	N	1
49	Post-	Lake[7]	Riverine	Slab on Grade	N	1
50	Post-	Lake[8]	Zone V Coastal	Pile	N	8
51	Post-	Lake[8]	Zone V Coastal	Pier	N	8
52	Post-	Lake[8]	Zone V Coastal	Solid Wall	N	8
53	Post-	Lake[8]	Zone V Coastal	Basement/Garden	B	4
54	Post-	Lake[8]	Zone V Coastal	Crawl Space	N	4
55	Post-	Lake[8]	Zone V Coastal	Fill	N	2
56	Post-	Lake[8]	Zone V Coastal	Slab on Grade	N	1

[1]Pre-FIRM construction in Census blocks with Riverine construction (e.g., Hazard Type = R).
[2]Post-FIRM construction in Census blocks with Riverine construction (e.g., HazardType = R).
[3]Pre-FIRM construction in Census blocks with Coastal construction (e.g., HazardType = C).
[4]Post-FIRM construction in Census blocks with Coastal construction (e.g., HazardType = C), subjected to A-Zone type flooding, including both Riverine and Coastal A-Zones (e.g., ZoneTypeID = 1).
[5]Post-FIRM construction in Census blocks with Coastal construction (e.g., HazardType = C), subjected to V-Zone type flooding (e.g., ZoneTypeID = 2).
[6]Pre-FIRM construction in Census blocks with Lakes construction (e.g., HazardType = L).
[7]Post-FIRM construction in Census blocks with Lakes construction (e.g., HazardType = L), subjected to A-Zone type flooding, including both Riverine and Coastal A-Zones (e.g., ZoneTypeID = 1).
[8]Post-FIRM construction in Census blocks with Lakes construction (e.g., HazardType = L), subjected to V-Zone type flooding (e.g., ZoneTypeID = 2).

5.6.3.2 RIVERINE BUILDING FOUNDATION TYPES

Foundation types were determined from either the Housing Characteristics report (DOE, 1993) or the Residential Energy Consumption report (EIA, 1997), with the exception of areas subjected to coastal flood hazards. Foundation types like pilings were not considered or mentioned in either report, but this information can be derived from the H. John Heinz III Center data collected for their report “The Hidden Cost of Coastal Hazards” (Heinz Center, 2000). Coastal hazard areas will be discussed later in this section.

When the two reports were compared, there were only moderate differences in the total percentages. For this reason, the Residential Energy Consumption (1997) Census division reporting was used to enhance accuracy of the foundation distributions available to the user. While the Residential Energy Consumption report does not consider multi-family residences of five units or less, it is assumed this distribution can be applied to these structures, since the numbers are so similar to the distributions found in the Housing Characteristics report.

For non-coastal development, Table 5-22 provides the recommended distribution of foundation types (basement, crawlspace, or slab on grade) for single- and multi-family residences of less than five units. Riverine foundation distributions do not vary by pre-FIRM or post-FIRM.

Table 5-21 Distribution of Foundation Types for Riverine Single-Family and Multi-Family Residences (% of total)

Census Division[1]	Pile[2]	Pier / Post	Solid Wall	Basement/ Garden Level	Crawl Space	Fill	Slab-on-Grade
New England	0%	0%	0%	81%	10%	0%	9%
Mid Atlantic	0%	0%	0%	76%	10%	0%	14%
East North Central	0%	0%	0%	68%	21%	0%	11%
West North Central	0%	0%	0%	75%	13%	0%	12%
South Atlantic[3]	0%	0%	0%	23%	35%	0%	42%
East South Central	0%	0%	0%	25%	49%	0%	26%
West South Central	0%	0%	0%	5%	38%	0%	57%
Mountain	0%	0%	0%	32%	29%	0%	39%
Pacific	0%	0%	0%	13%	45%	0%	42%

[1]Census Division list of states provided in Table 3-1.

[2]Based on A Look at Residential Energy Consumption in 1997 (Nov 1999) Table HC1-9b through HC1-12b as a percent of single-family housing units.

[3]Puerto Rico and U.S. Virgin Islands use South Atlantic values.

For the Tsunami states, foundation type data is taken directly from NSI 2022 according to the categories listed in Table 5-23. For the U.S. Virgin Islands, values provided in the VI dataset were used. For Puerto Rico, Guam, American Samoa and Northern Mariana Islands, a default value of slab was applied.

Table 5-22 Foundation Type Value Description

NSI Designation	Description	Hazus Foundation Type
I	Pile	1
P	Pier	2
W	Solid Wall	3
B	Basement	4
C	Crawl	5
F	Fill	6
S	Slab	7

5.6.3.3 RIVERINE BUILDING FIRST FLOOR HEIGHT ABOVE GRADE

For the sake of consistency, it was determined that the measurement of floor height from grade to the top of the finished floor for both pre-FIRM and post-FIRM would be a good basis for default values.

When detailed local data is available, users may decide to compare local data with Hazus data and update values for variables such as pre-FIRM and post-FIRM foundation distributions and their associated FFHAG. Contact the Hazus Help Desk (see Section 1.5) for guidance on best practices to customize specific variables within a Study Region. Table 5-24 provides the default pre-FIRM or post-FIRM elevations for each foundation type in riverine flood hazard areas.

Table 5-23 Default First Floor Heights Above Grade to Top of Finished Floor (Riverine)

ID	Foundation Type	Pre-FIRM	Post-FIRM
1	Pile	7 feet	8 feet
2	Pier (or post and beam)	5 feet	6 feet
3	Solid Wall	7 feet	8 feet
4	Basement (or Garden Level)	4 feet	4 feet[1]
5	Crawlspace	3 feet	4 feet
6	Fill	2 feet	2 feet
7	Slab	1 foot	1 foot[1]

Source Data: Expert Opinion

[1]Typically not allowed in SFHA post-FIRM but may exist.

Note that the heights shown here are default values. In some cases, regulations are written to include freeboard above the BFE. Additionally, typical engineering design will shift from one foundation type to another, depending on the height necessary to elevate the structure above BFE. Therefore, it is recommended to use the following guidelines for post-FIRM foundation distributions:

- *Piles*: Used when the BFE plus freeboard is 8 feet or greater.
- *Piers:* Used when the BFE plus freeboard is less than 6 feet. If BFE plus freeboard is greater than 6 feet, typical construction practice is to use other foundation types such as solid walls or piles.
- *Solid Walls:* Used when the BFE plus freeboard is less than 8 feet. If the BFE plus freeboard is greater than 8 feet, typical construction practice is to use piles.
- *Basements:* Typically, not allowed in post-FIRM development in the SFHA. The user should establish the post-FIRM distribution to match what is occurring in the regulated areas.
- *Crawlspaces:* Used when the BFE plus freeboard is less than 4 feet. If BFE plus freeboard is greater than 4 feet, typical construction practice is to use other foundation types such as piers, solid walls, or piles.
- *Fill:* Used when the BFE plus freeboard is less than 2 feet. If the BFE plus freeboard is greater than 2 feet, typical construction practice is to use other foundation types such as crawlspace, piers, solid walls, or piles.
- *Slab-on-Grade:* Typically not allowed in post-FIRM development within the SFHA since fill is typically required to reach BFE. The user should establish the post-FIRM distribution to match what is occurring in the regulated areas.

5.6.3.4 COASTAL BUILDING FOUNDATION TYPES

The H. John Heinz III Center for Science, Economics and the Environment has developed a report discussing coastal erosion along the U.S. coastline. Part of this effort entailed collecting data from several coastal communities in areas along coastlines. Their study included site visits to survey the areas of interest. While the data they developed was collected for a different task, it contained detailed information on the structures along U.S. coastlines. For additional information regarding the methodology of data collection and the complete metadata discussion, please refer to the Heinz Center's report (Heinz Center, 2000).

The Heinz Center's data was supplied with the necessary metadata allowing analysis to identify potential usefulness for the Flood Model. The data contained information regarding foundation types and the structures flood zone (i.e., Zone A, Zone V, etc.). The data was graphically plotted in order to find distinct construction features by geographic region and appropriate flood zone for the development of a modifier table. Table 5-25 shows the table for pre-FIRM structures that is applied to those Census blocks that are within or intersect the coastal FIRM zones data from the Heinz Center report. The Coastline areas are defined in Table 5-26.

Table 5-24 Distribution of Coastal Pre-FIRM Foundation Types (% of Total)

Coastline	Pile	Pier	Solid Wall	Basement	Crawl Space	Fill	Slab
Pacific	7%	7%	1%	2%	46%	0%	37%
Great Lakes	0%	1%	0%	0%	29%	0%	70%
North Atlantic	47%	7%	2%	0%	34%	0%	10%
South Atlantic[1]	34%	7%	2%	0%	20%	0%	37%
Gulf of Mexico	34%	7%	1%	1%	21%	0%	36%

Source Data: The H. John Heinz III Center for Science, Economics and the Environment study data 2000, and expert opinion.

[1]Puerto Rico and U.S. Virgin Islands use South Atlantic values.

Table 5-25 Coastline Definitions

Coastline	States and Territories
Pacific	AK, CA, HI, OR, WA
Great Lakes	IL, IN, MI, MN, NY[1], OH, PA[1] , WI
North Atlantic	CT, MA, ME, NH, NJ, NY[1], PA[1], RI
South Atlantic	DC, DE, FL, GA, MD, NC, PR, SC, VA, VI
Gulf of Mexico	AL, LA, MS, TX

[1]States with both Coastal and Great Lakes areas utilize both foundation distributions.

Table 5-25 shows that the Heinz Center did not find any structures located on elevated fill in any of their sample communities. The field for elevated fill was kept so users could modify the foundation types to include this classification if it exists within their community. The communities investigated by the Heinz Center had an unusually high number of pile foundations due to modern hurricane experiences. To accommodate this, the North Atlantic, South Atlantic and Gulf Coast Zones V were modified slightly to increase the use of pier foundations and reduce the pile foundations. The team also reduced the slab-on-grade foundations and increased the use of the crawlspace foundations for the Great Lake Zone A.

For post-FIRM structures, Table 5-27 provides the default distribution for the Flood Model. It should be noted that the Heinz Center data includes some foundation types that should not have been utilized within the flood zones indicated. For example, the North Atlantic Zone V (Coastal) data includes some slab-on-grade structures. This may be an indication that some of the structures were built just before or were under construction while the ordinances were being put in place.

Table 5-26 Percent Distribution of Coastal Post-FIRM Foundation Types by Coastal Zones

Zone	Coastline	Pile	Pier	Solid Wall	Basement	Crawlspace	Fill	Slab-on-Grade
Zone V	Pacific	60%	25%	0%	0%	10%	0%	5%
Zone V	Great Lakes	5%	0%	10%	0%	30%	0%	55%
Zone V	North Atlantic	75%	15%	5%	0%	0%	0%	5%
Zone V	South Atlantic[1]	80%	15%	2%	0%	1%	0%	2%
Zone V	Gulf of Mexico	85%	10%	2%	0%	1%	0%	2%
Zone A	Pacific	20%	5%	0%	0%	55%	0%	20%
Zone A	Great Lakes	5%	0%	10%	0%	30%	0%	55%
Zone A	North Atlantic	40%	10%	5%	0%	30%	0%	15%
Zone A	South Atlantic[1]	50%	15%	2%	0%	20%	0%	13%
Zone A	Gulf of Mexico	50%	15%	2%	0%	20%	0%	13%

Source Data: The H. John Heinz III Center for Science, Economics and the Environment study data 2000 and expert opinion

[1]Puerto Rico and U.S. Virgin Islands use South Atlantic values.

For the Tsunami states, foundation type data is taken directly from NSI 2022 according to the categories listed in Table 5-25. For the U.S. Virgin Islands, values provided in the VI dataset were used. For Puerto Rico, Guam, American Samoa and Northern Mariana Islands, a default value of slab was applied.

5.6.3.5 COASTAL BUILDING FLOOR HEIGHT ABOVE GRADE

For coastal flood areas, a consistent measure of floor height from grade to the top of the finished floor was selected for both Zone A and Zone V heights. Within the Flood Model, the floor height was adjusted to reference the top of the lowest finished floor to allow a height consistent with the coastal damage curves.

Table 5-28 provides the default first floor height above grade for each foundation type in coastal flood hazard areas. This table also shows the changes in foundation type and height by flood hazard zone and pre-FIRM or post-FIRM. Typically, foundations like slab-on-grade, fill, and crawlspaces are not allowed in Zone V construction, but there will be occasional communities where these foundations exist in some numbers, due to map revisions or delays in compliance enforcement. For this reason, Zone V elevations are provided for these foundation types. Also note that for pier foundation types there are different values for Post-FIRM Zone A as compared to Post-FIRM Zone V.

Table 5-27 Default First Floor Height Above Grade to Top of Finished Floor (Coastal)

ID	Foundation Type	Pre-FIRM	Post-FIRM Zone A	Post-FIRM Zone V
1	Pile (or column)	7 feet	8 feet	8 feet
2	Pier (or post and beam)	5 feet	6 feet	8 feet
3	Solid Wall	7 feet	8 feet	8 feet
4	Basement (or Garden Level)	4 feet	4 feet[1]	4 feet[1]
5	Crawlspace	3 feet	4 feet	4 feet[1]
6	Fill	2 feet	2 feet	2 feet[1]
7	Slab	1 foot	1 foot[1]	1 foot[1]

Source Data: Expert Opinion

[1] Typically not allowed but may exist.

The heights shown here are default values for coastal areas. In some cases, regulations are written to include a freeboard above the BFE. Additionally, typical engineering design will shift from one foundation type to another depending on the height requirements to elevate the structure above BFE. It is recommended to use the following guidelines for post-FIRM foundation distributions:

- *Pile*: This foundation is typically utilized when the BFE plus freeboard is 8 feet or greater.
- *Pier:* This foundation is typically utilized when the BFE plus freeboard is less than 6 feet (Zone A) and 8 feet (Zone V). If BFE plus freeboard is greater than these heights, typical construction practice is to use other foundation types, such as solid walls or piles.
- *Solid Wall:* This foundation is typically utilized when the BFE plus freeboard is less than 8 feet. If the BFE plus freeboard is greater than 8 feet, general construction practice is to use piles.
- *Basement:* This is typically not allowed in post-FIRM development. The user should establish the post-FIRM distribution to match what is actually occurring in the regulated areas.
- *Crawlspace*: This foundation is typically utilized when the BFE plus freeboard is less than 4 feet. If BFE plus freeboard is greater than 4 feet, typical construction practice is to use other foundation types such as piers, solid walls, or piles. This foundation type is typically not allowed in areas identified as Zone V.
- *Fill:* This foundation is typically utilized when the BFE plus freeboard is less than 2 feet. If the BFE plus freeboard is greater than 2 feet, typical construction practice is to use other foundation types such as crawlspace, piers, solid walls, or piles. This foundation type is typically not allowed in areas identified as Zone V.
- *Slab-on-Grade:* This is typically not allowed in post-FIRM development. The user should establish the post-FIRM distribution to match what is actually occurring in the regulated areas.

As with the values in Table 5-24, the foundation results in Table 5-28 were slightly modified to account for the unusually high percentage of pile foundations (see Section 5.6.3.4).

5.7 Other Hurricane Building Characteristics

For the hurricane general building type to hurricane specific building type mapping scheme, as shown in Table 4-4, aerial photographs were used to estimate the percentage of one and two-story houses in PR and VI. Data from the RCMP was used to identify the number of stories, shape, and specific occupancy. Historic building codes were used to determine building types in different parts of the country (National Building Code vs. International Building Code, etc.).

For the hurricane specific building type to hurricane wind building characteristics (WBCs) mapping scheme, the following sections provide an overview of each of these characteristics.

5.7.1 Roof Shape

Roof shape can have three values in Hazus: Hip, Gable, and Flat. The shape of a roof, siting, fastening, and composition will determine the structure's resilience during a hurricane. Coastal areas especially require corrosion-resistant structural connectors. A hip roof is a type of roof where all sides slope downwards to the walls, usually with a gentle slope. Hipped roofs have no gables or other vertical sides to the roof. A gable roof is a classic, most commonly occurring roof shape in temperate climate areas. It consists of two roof sections sloping opposite directions and placed so the highest, horizontal edges meet to form the roof ridge. A flat roof is almost level in contrast with sloped roofs. They are mostly used in arid climates and allow the roof space to be used for living space or a living roof. Flat roofs are often used for commercial buildings throughout the world.

5.7.2 Roof Cover Type

Roof cover refers to the layers of materials that make up the roof above roof deck. Built-up roof (BUR) covers are composed of multiple plies of roofing felts adhered to each other and to the insulation substrate with a full mop of hot asphalt, coal tar, or cold adhesive. The number of plies of roofing felt ranges from three to five. Roofing felts are commonly made of polyester, organic or glass-based materials. The surfacing on BUR covers is most often gravel or slag.

Single-ply Membrane (SPM) covers are normally attached to the insulation substrate by adhesives (hot asphalt or cold applied materials) or by mechanical fasteners. Adhered SPM covers can be fully adhered or partially adhered. The adhesive in partially adhered SPM covers will typically have 50% coverage in the central portions of the roof and greater coverage at or near the edges and corners of the roof. Common membranes are thermoplastic membranes, thermoset membranes, modified bitumen membranes, and liquid applied membranes.

For Puerto Rico and the U.S. Virgin Islands, four additional roof cover types are modeled: Reinforced Concrete (rccnt), Corrugated Steel (rccor), Elastomeric Paint (rcpnt): and Standing Seam Metal (rcssm). More information about these roof cover types can be found in *Hazus Hurricane Wind for Puerto Rico and the U.S. Virgin Islands* (FEMA, 2021a).

Hazus WBCs include roof covering conditions with values of New, Good, and Poor, and secondary water resistance with values of Yes and No.

5.7.3 Roof Deck Attachment

Roof deck is defined as boards or plywood nailed to the roof rafters or trusses. It is also called roof sheathing and can fail during a high-wind event if not properly installed or insufficiently fastened. Sheathing loss is one of the most common structural failures in hurricanes. Fastener spacing and size requirements for coastal constructions are typically different than for non-coastal areas.

For all roof shapes, Hazus uses two roof fastener conditions of 6-penny and 8-penny nails, different spacing options of 6x12 inches or 6x6 inches, and deck age categories of New/Average or Old.

5.7.4 Roof Frame and Wall Connections

Framing the roof properly is important for the stability of the entire building envelope. The frame of the roof needs to be tied down appropriately, especially in high-wind situations. Hazus WBCs include Strapped and Toe-Nailed roof-wall connection conditions and joist spacing of 4 or 6 feet.

5.7.5 Fenestrations

Fenestration is the design, construction, or presence of openings in a building. Openings need to be designed to be water and wind resistant. A successful moisture barrier system will limit water infiltration into unwanted areas and allow drainage and drying of wetted building materials.

Two types of windows are used for single-family homes (WSF1, WSF2, MSF1, MSF2): regular and jalousie. A regular window (wtnor) is a typical single pane glass window. A jalousie window (wtjal) consists of angled glass louvers and are widely used in tropical climates. The louvers can be tilted open and closed by turning a crank to control airflow.

Hazus WBCs include Window Area of Low, Medium or High and Shutters as Yes or No. For unshuttered houses with garages, WBCs for garage doors include None, Weak, or Standard Door. For shuttered houses with garages, the WBCs for garage doors are None or meet the South Florida Building Code 1994 standards.

5.7.6 Other Characteristics

Other WBCs consider other structure characteristics that influence building performance during wind events. For example, Hazus uses a WBC for Wind Debris to include Residential, Residential and Commercial Mix, Varies by Direction, and None. Units per floor of single unit versus multi-unit is another WBC. For masonry structures, there is a WBC for with and without reinforcing. Finally, there is a Tie Down WBC with Yes and No values.

5.7.7 Wind Building Characteristic Mapping Schemes

Like the development of the specific building types, surveys were used to develop the additional WBCs, focusing primarily on roof types. Aerial and/or street level photographs were used to estimate roof shape and roof cover type across the U.S. In cases where the homes had a roof, which was a combination of a hip section and a flat section, it was classified as a hip roof building. The same classification scheme was used for homes with combined flat and gable roofs. In cases where the roof was a hip/gable combination, the building was classified by the dominant roof style. Roof cover data was also collected from the Florida RCMP. Other characteristic data were collected using a survey sent to contractors familiar with construction practices for hurricane-prone regions.

More details on these mapping schemes can be found in the *Hazus Hurricane Model Technical Manual* (FEMA, 2024b).

5.8 Other Tsunami Building Characteristics

When FEMA developed the Tsunami Methodology, the existing Earthquake and Flood Model-specific inventory attributes were leveraged, rather than requiring the development of new tsunami-specific vulnerability attributes. The Tsunami building damage functions in Hazus are based entirely on specific earthquake building types and seismic design levels used by the Earthquake Model. The estimate of finished floor height required to estimate the depth of tsunami within structures is based on the Flood Model foundation types and finished floor height relationships.

Because the Tsunami Methodology uses these other existing Hazus tables for certain building characteristics, only one new unique Tsunami inventory table was required for modeling. The required attributes for tsNsiGbs are summarized later in this section and it is the only inventory dataset required to produce Tsunami GBS losses and casualties.

To leverage the GBS valuation python script which was used to update the GBS valuations for the U.S., Puerto Rico and U.S. Virgin Islands for Hazus 6.0, the Hazus 5.1 data for American Samoa, Guam and Northern Mariana Islands was first improved with new footprint data and then restructured into the NSI 2022 schema.

As discussed in Section 3.7, the Pacific Territories were improved by adding new structures and consolidating duplications within the Hazus 5.1 tsNsiGbs table. For American Samoa, Guam and Northern Mariana Islands, new structures that were created from footprint data did not have an occupancy type; therefore, this information was estimated using Hazus 5.1 data. Thiessen polygons were created from the existing Hazus 5.1 structures. A default occupancy type column was added to the Thiessen polygons and populated based on the general occupancy type associated with the specific occupancy type of the point (e.g., RES3A is Residential). Table 5-29 shows the crosswalk of specific occupancy type to the associated default occupancy type that was assigned to these new structures.

Table 5-28 Crosswalk of Specific Occupancy Type/ID to Default Occupancy Type/ID

Specific Occupancy Type	Specific Occupancy Type ID	Default Occupancy Type	Default Occupancy Type ID
RES1	1	RES1	1
RES2	2	RES1	1
RES3A	3	RES1	1
RES3B	4	RES1	1

Specific Occupancy Type	Specific Occupancy Type ID	Default Occupancy Type	Default Occupancy Type ID
RES3C	5	RES1	1
RES3D	6	RES1	1
RES3E	7	RES1	1
RES3F	8	RES1	1
RES4	9	RES1	1
RES5	10	RES1	1
RES6	11	RES1	1
COM1	12	COM1	12
COM2	13	COM1	12
COM3	14	COM1	12
COM4	15	COM1	12
COM5	16	COM1	12
COM6	17	COM1	12
COM7	18	COM1	12
COM8	19	COM1	12
COM9	20	COM1	12
COM10	21	COM1	12
IND1	22	IND1	22
IND2	23	IND1	22
IND3	24	IND1	22
IND4	25	IND1	22
IND5	26	IND1	22
IND6	27	IND1	22
AGR1	28	AGR1	28
REL1	29	REL1	29
GOV1	30	GOV1	30
GOV2	31	GOV2	31
EDU1	32	EDU1	32
EDU2	33	EDU2	33

These polygons were then spatially joined to the point footprint data. The new structure data was assigned the Thiessen polygon’s default occupancy type. Area square footage was assigned the footprints square footage. New structures in American Samoa, Guam and Northern Mariana Islands also received the following default values, depicted in Table 5-30.

Table 5-29 Additional Default Values for American Samoa, Guam and Northern Mariana Islands

Attribute	Default Value
Foundation Type ID	7 (slab on grade)
First Floor Height	1 foot
Number of Stories	1

The consolidation process impacted the characteristic assignment for American Samoa, Guam and Northern Mariana Islands. When points were consolidated, the single representative point for the structure was assigned the most occurring values for occupancy type (SOccTypeID field) and foundation type (FoundTypeId field) in the group of structures. In cases where the most common value was tied between multiple values, these structures were spatially joined to the Thiessen polygon and assign the attributes of the polygon. The attributes number of stories (NStories field) and first floor height (FirstFloorHt field) were assigned the mean value of the grouped structures, which were then rounded to the nearest whole number. The building's area was calculated by multiplying the footprint area by the number of stories.

The improved data for American Samoa, Guam and Northern Mariana Islands were spatially joined to the 2020 Census blocks to assign each building the updated Census block identification information. Finally, each dataset was converted to the NSI 2022 data schema and ran through the General Building Stock valuation python script.

With all the data in a common format, a second python script was used to update the tsNsiGbs attributes for the Tsunami states and territories (California, Oregon, Washington, Alaska, Hawaii, Puerto Rico, U.S. Virgin Islands, Guam and Northern Mariana Islands). In the script, data source (reformatted to the NSI schema) was updated using the following methods to create the tsNsiGbs table. Each attribute was updated using the methods described in Table 5-31.

Table 5-30 Tsunami Model National Structure Inventory Field Descriptions and Data Types

Field Name	Description	Data Type
NsiID	A unique ID derived from the concatenation of the specific occupancy type, the Census Block 2020 ID and ObjectID from the reformatted data source.	String Data: Max 30 characters
EqBldgTypeId*	The index value based on the specific earthquake building type. For data supplied from the NSI 2022 data source (AK, CA, HI, OR and WA), this data was based on the implementation of NSI 2022 exterior wall types from Lightbox parcel data, number of stories when defined as a Census Urban area, and Year Built. For VI this was already defined in the data source (FEMA, 2020). PR, AS, GU and MP values were identified using the tsSOccupSBTPct table within the Hazus 5.1 State databases.	Integer Data: Small integer type used for ID fields

Field Name	Description	Data Type
EqDesignLevelId*	The index value based on seismic design level. This value is based on the implementation of benchmark years by state and year built (see Table 5-31). For Tsunami states, if the year built was available from parcel data, this value was used. If data was unavailable, median year built from Census data was used. The median year built from Census data was used for all territories. Note that in the case of AS, MP, GU and VI, the Median Years are still based on the Hazus 5.1 data as the ACS has not been updated for those areas.	Integer Data: Small integer type used for ID fields
SOccTypeId	An index value based on the Hazus Specific Occupancy type. This value was mapped from the data source specific occupancy type.	Integer Data: Small integer type used for ID fields
FoundTypeId	An index value based on the Hazus Specific Flood Foundation Type.	Integer Data: Small integer type used for ID fields
CBFips	The Census block identification number, which was obtained by spatially joining the structure point data to the 2020 Census block data.	String Data: Max 15 characters
NStories	The number of stories. The updated NSI 2022 NUM_Story Field was mapped to NStories. This was used in the Earthquake Specific Building Type assignments when points were located in Urban areas defined by the Census. Due to anomalies in the NSI data, number of stories in Urban Clusters and Rural areas was not used. Because NSI 2022 data was not available for AS, MP and GU, a default value of 1 story was applied for new structures in those territories.	Integer Data: Regular integer type used for data fields
AreaSqft	The building areas in square feet. For structures from the NSI 2022 data source, these values were mapped from the SQFT field. Because NSI 2022 data was not available for AS, GU, and MP, AreaSqft was derived from other building footprint data. See Section 5.2 for additional information.	Decimal Data: Numeric type with 38 digits and 8 decimal places
PerSqftAvgVal	The per square foot average value. This value is calculated by dividing the ValStruct by the AreaSqft.	Decimal Data: Numeric type with 38 digits and 20 decimal places
FirstFloorHt	FirstFloorHt is an estimate of the FFHAG in feet that is related to foundation type. For NSI 2022 data for AK, CA, HI, OR, and WA and the FEMA NHRAP VI data, the foundation type field was cross walked to the respective index value as shown in Table 5-20 and the FirstFloorHt values were directly used. For PR, AS, GU and MP, the default value 7 (slab foundation type) and FirstFloorHt of 1 was applied.	Decimal Data: Numeric type with 38 digits and 8 decimal places

Field Name	Description	Data Type
ValStruct	The replacement values of structures in U.S. dollars. These values were calculated using the valuation script developed for the GBS updates and mapped to the appropriate field in the tsNsiGbs table. Since 2020 ACS data were not yet available for AS, MP, GU and VI prior to Hazus 6.0 development, the existing 2019 Income Ratios for VI were used in estimating the RES1 replacement costs and for AS, GU and MP the average RES1 replacement cost values were used with no adjustment based on median income or construction class weights. See Section 6 for additional information regarding valuation and cost models.	Decimal Data: Numeric type with 38 digits and 8 decimal places
ValCont	The replacement values of contents in U.S. dollars. These values were calculated using the valuation script developed for the GBS updates and mapped to the appropriate field in the tsNsiGbs table. See Section 6 for additional information regarding valuation and cost models.	Decimal Data: Numeric type with 38 digits and 8 decimal places
ValOther	The replacement values of items categorized as “other” in U.S. dollars.	Decimal Data: Numeric type with 38 digits and 8 decimal places
ValVehic	The replacement values of vehicles in U.S. dollars. If the vehicle values were present in the NSI 2022 source data, these values were used for ValVehic, otherwise these fields were left blank.	Decimal Data: Numeric type with 38 digits and 8 decimal places
MedYrBlt	The MedYrBlt represents the median year built for all structures within the Census block. For structures from the NSI 2022 where the year built was provided by parcel data, this value was used. If unavailable, the median year built was pulled from Census 2020 data. For PR, GU, AS and MP the median year data was pulled from the existing Census 2010 data as the ACS data was not yet available.	Integer Data: Regular integer type used for data fields
Pop2pmU65	The value of the under the age of 65 daytime population. This data was present in the NSI 2022 data source based on the Longitudinal Household Employer Dynamic Database (LEHD) and used directly. For PR, VI, AS, GU and MP this population value was not present in the data source. To calculate this value, the under 65 day population was distributed to buildings based on area and occupancy type in accordance with the Hazus CDMS tool for preparing inventories for the Advanced Earthquake Building Model (AEBM)[1] Table 5-36 and the under 65 ratio was determined from hzDemographics table (see Section 5.9). For EDU2[2], the Pop2pmU65 was calculated by taking the sum of employees and students and multiply it by 0.995 (99.5%).	Integer Data: Regular integer type used for data fields

Field Name	Description	Data Type
Pop2pmO65	The value of the over the age of 65 daytime population. This data was present in the NSI 2022 data source based on the LEHD and used directly. For PR, VI, AS, GU and MP these population values were not present in the data source. To calculate these values, the over 65 day population was distributed to buildings based on area and occupancy type in accordance with the Hazus CDMS tool for preparing inventories for the AEBM[1] and the over 65 ratio was determined from hzDemographics table (see Section 5.9). For EDU2[2], the Pop2pmO65 was calculated by taking the sum of employees and students and multiplying it by 0.005 (0.5%).	Integer Data: Regular integer type used for data fields
Pop2amU65	The value of the under the age of 65 nighttime population. This data was present in the NSI 2022 data source based on the LEHD and used directly. For PR, VI, AS, GU and MP this population value was not present in the data source. To calculate this value, the under 65 night population was distributed to buildings based on area and occupancy type in accordance with the Hazus CDMS tool for preparing inventories for the AEBM[1] and the under 65 ratio was determined from hzDemographics table (see Section 5.9). For EDU2[2], Pop2amU65 were calculated by multiplying the Pop2pmU65 by 0.005 (0.5%).	Integer Data: Regular integer type used for data fields
Pop2amO65	The value of the over the age of 65 nighttime population. This data was present in the NSI 2022 data source based on the LEHD and used directly. For PR, VI, AS, GU and MP this population value was not present in the data source. To calculate this value, the over 65 night population was distributed to buildings based on area and occupancy type in accordance with the Hazus CDMS tool for preparing inventories for the AEBM[1] and the over 65 ratio was determined from hzDemographics table (see Section 5.9). For EDU2[2], Pop2amO65 were calculated by multiplying the Pop2pmO65 by 0.005 (0.5%).	Integer Data: Regular integer type used for data fields

[1] For more information, see Hazus Comprehensive Data Management System User Guidance (FEMA, 2019).

[2] This method was developed to emulate the USACE LEHD education ratios for EDU2 that used HIFLD Open Data: A statewide sample of all Colorado education occupancy types was utilized to derive the ratio since Colorado had a large sample available in both HIFLD and NSI 2022 Open Data that included both EDU1 and EDU2. These values reflected a 0.5% over 65 population compared to a 99.5% under 65 population and that nighttime occupancy was approximately 0.5% of daytime.

**Note: The earthquake building type and design levels in the Tsunami model were not synchronized with the new Hazus 6.1 earthquake mapping schemes.*

All structure locations were anonymized by randomly generating points for the number of structures within a given Census block and placing those points within the Census block's dasymetric boundary (see Section 3.2). For each structure, a random latitude and longitude were generated within a bounding box that represents the extent of the Census block's dasymetric geometry. Since this method only allows random points to be placed within a rectangular shape an additional process was added. This process checks to see whether the new latitude and longitude was generated within the Census block's dasymetric geometry. If so, then the new latitude and longitude was assigned to the structure. If the latitude and longitude fell within the bounding extent but outside of the dasymetric area, then a new random latitude and longitude were generated. This process will repeat up to 100 times as it attempts to place the structures randomly within the Census block's dasymetric geometry. If after 100 attempts, it still has not created a passable random latitude and longitude, then the centroid within the polygon boundary is assigned. The latitude and longitude values that were randomized were used to replace the original tsNsiGbs Latitude and Longitude attributes. Latitude and Longitude are in WGS 1984 coordinate system.

Distribution of the population by age and general occupancy type was performed by first calculating a population distribution ratio for each NSI point. The ratio is the NSI point building area divided by the total building area for the general occupancy type for the Census tract and provided the basis for the Census population distribution to the NSI points (Table 5-32), with few exceptions described below.

Table 5-31 Distribution of 2010 Census Population to Tsunami NSI for Territories Except Puerto Rico

Census 2010	National Structure Inventory
O65ResidDay	Distribute to Residential (all res except RES4 & RES6) Pop2pmO65
U65ResDay	Distribute to Residential (all res except RES4 & RES6) Pop2pmU65
O65ResNight	Distribute to Residential (all res except RES4 & RES6) Pop2amO65
U65ResNight	Distribute to Residential (all res except RES4 & RES6) Pop2amU65
WorkingCom	Distribute to Commercial (and GOV1, exclude COM6 & COM10) Pop2pmU65
WorkComNight	Distribute to Commercial (and GOV1, exclude COM6 & COM10) Pop2amU65
WorkingInd	Distribute to Industrial Pop2pmU65
WorkIndNight	Distribute to Industrial Pop2amU65
SchoolEnrollmentKto12	Distribute to EDU1 Pop2pmU65
SchoolEnrollmentCollege	Distribute to EDU2* Pop2pmU65

** Based on a ratio determined by the total EDU2 building area for the State, based on the assumption that college students come from all surrounding tracts. Puerto Rico used standard GBS approaches for these values.*

The use of population by building area (given as square footage) estimates from FEMA (2023) and the *Hazus Earthquake Model Technical Manual* (FEMA, 2024) were utilized to increase accuracy when assigning population to essential and high occupancy facilities. These estimates provide the peak day and peak night defaults utilized by the Hazus CDMS tool for preparing inventories for the Advanced Earthquake Building Model (AEBM) (Table 5-33). The defaults were used to provide a quality check of the results of distributing populations from U.S. Census aggregated data to the NSI points. Rounding the NSI point populations to integers resulted in some loss of fractions. Some manual editing was required, and checks were made to ensure that the night and day populations were balanced and did not exceed state level populations. For example, a check was made to ensure daytime populations did not exceed nighttime for the entire territory.

Table 5-32 Tsunami Estimated Peak Day and Night Occupancy Loads for Territories except Puerto Rico

Occupancy	Description	Peak Day (~2:00 pm) (ft²/person)	Peak Night (~2:00 am) (ft²/person)	Sources for Estimate
AGR1	Agriculture	250	12,500	Hazus Flood for employees; Hazus Earthquake for day and night ratios
COM1	Retail Trade	167	8,333	FEMA (2023); Hazus Earthquake for day and night ratios
COM10	Parking	-	-	Not applicable
COM2	Wholesale Trade	900	45,000	Hazus Flood for employees; Hazus Earthquake for day and night ratios
COM3	Personal and Repair Services	590	5,900	Similar to IND2, Hazus Earthquake for day and night ratios
COM4	Professional/Technical Services	250	12,500	FEMA (2023); Hazus Earthquake for day and night ratios
COM5	Banks	250	12,500	FEMA (2023); Hazus Earthquake for day and night ratios
COM6	Hospital	200	667	FEMA (2023); Hazus Earthquake for day and night ratios
COM7	Medical Office/Clinic	200	-	FEMA (2023); Hazus Earthquake for day and night ratios
COM8	Entertainment & Recreation	75	-	Hazus Tsunami
COM9	Theaters	75	-	Hazus Tsunami
EDU1	Grade Schools	71	3,571	FEMA (2023); Hazus Earthquake for day and night ratios
EDU2	Colleges/Universities	83	4,167	FEMA (2023); Hazus Earthquake for day and night ratios
GOV1	General Services	250	12,500	FEMA (2023); Hazus Earthquake for day and night ratios
GOV2	Emergency Response	300	300	Hazus Tsunami
IND1	Heavy	550	5,500	Hazus Flood for employees; Hazus Earthquake for day and night ratios

Occupancy	Description	Peak Day (~2:00 pm) (ft²/person)	Peak Night (~2:00 am) (ft²/person)	Sources for Estimate
IND2	Light	590	5,900	Hazus Flood for employees; Hazus Earthquake for day and night ratios
IND3	Food/Drugs/Chemicals	540	5,400	Hazus Flood for employees; Hazus Earthquake for day and night ratios
IND4	Metals/Minerals Processing	730	7,300	Hazus Flood for employees; Hazus Earthquake for day and night ratios
IND5	High Technology	300	3,000	Hazus Flood for employees; Hazus Earthquake for day and night ratios
IND6	Construction	250	2,500	Hazus Flood for employees; Hazus Earthquake for day and night ratios
REL1	Churches and Other Nonprofit	20	-	Hazus Tsunami
RES1	Single-Family Dwelling	1,201	841	Based on National median area (2,169ft²) and average household (2.58) size from U.S. Census. Hazus Earthquake for day and night ratios
RES2	Manufactured Housing	461	323	FEMA (2023); Hazus Earthquake for day and night ratios
RES3A	Duplex	461	323	FEMA (2023); Hazus Earthquake for day and night ratios
RES3B	Triplex / Quads	461	323	FEMA (2023); Hazus Earthquake for day and night ratios
RES3C	Multi-dwellings (5 to 9 units)	461	323	FEMA (2023); Hazus Earthquake for day and night ratios
RES3D	Multi-dwellings (10 to 19 units)	461	323	FEMA (2023); Hazus Earthquake for day and night ratios
RES3E	Multi-dwellings (20 to 49 units)	461	323	FEMA (2023); Hazus Earthquake for day and night ratios
RES3F	Multi-dwellings (50+ units)	461	323	FEMA (2023); Hazus Earthquake for day and night ratios

Occupancy	Description	Peak Day (~2:00 pm) (ft²/person)	Peak Night (~2:00 am) (ft²/person)	Sources for Estimate
RES4	Temporary Lodging - Hotel	2,105	400	FEMA (2023); Hazus Earthquake for day and night ratios
RES5	Institutional Dormitory	2,105	400	FEMA (2023); Hazus Earthquake for day and night ratios
RES6	Nursing Home	115	115	Hazus Tsunami

** General guidance only, peak loads provide worst case estimates of casualties, actual occupants may vary substantially by geography, season, time of day, day of week, holidays, etc. Puerto Rico used standard GBS approach for these values.*

Population distribution to essential and high occupancy facilities for the territories was done separately to ensure peak day and night values were reasonable. Table 5-34 summarizes the day and night, as well as the under and over 65 population distribution for these occupancy types based on building area.

Table 5-33 Tsunami Population Distributions for Special Occupancy Cases for Territories Except Puerto Rico (Area=ft²)

Specific Occupancy	Pop2pmU65	Pop2pmO65	Pop2amU65	Pop2amO65
Hospitals (COM6)	0.95 * Area/200	0.05 * Area/200	0.95 * Area/667	0.05 * Area/667
Emergency Services (GOV2)	Area/300	NA	Area/300	NA
Hotels (RES4)	0.95 * Area/2,105	0.05 * Area/2,105	0.95 * Area/400	0.05 * Area/400
Nursing Homes (RES6)	0.05 * Area/115	0.95 * Area/115	0.05 * Area/115	0.95 * Area/115

It is also important to note that the Tsunami Model casualty interface includes a processing step where the user is presented with the day and night, under and over 65 exposed populations that can be edited to include any transient or visitor populations common in tsunami risk areas such as beach populations and cruise ships.

The following sections provide details on how particular fields were derived for Tsunami NSI data.

5.8.1 Earthquake-Derived Characteristics

For data supplied from the NSI 2022 data source (Alaska, California, Hawaii, Oregon and Washington), this data was based on the implementation of NSI 2022 exterior wall types from Lightbox parcel data, number of stories when defined as a Census Urban area, and Year Built. For U.S. Virgin Islands, this was already defined in the data source (FEMA, 2020). Values for Puerto Rico, American Samoa, Guam and Northern Mariana Islands were identified using the tsSOccupSBTPct table within the existing Hazus 5.1 State databases.

The Tsunami Model also has a field called EqDesignLevelId that represents the Earthquake Model seismic design level of the structure, as shown in Table 5-35.

Table 5-34 Hazus Tsunami Seismic Design Levels by Field Name

DesignLevelID	EqDesignLevelId	DesignLevelDesc
1	PC	Pre-Code
2	LC	Low Code
3	MC	Moderate Code
4	HC	High Code
5	LS	Low-Code - Special
6	MS	Moderate-Code - Special
7	HS	High-Code - Special

The Earthquake Model with the release of Hazus 6.1 now uses a tract-level mapping scheme to assign seismic design level and earthquake building type. These have not yet been updated for the Hazus 6.1 tsunami building type data. For the Tsunami states and territories, an approach utilizing the construction year based on NSI 2022 parcel data when available or the estimated Median Year Built from Census when not available, and typical benchmark code adoption years for each State and Territory was used to assign a seismic design level for structures within the Census block. Note that in the case of American Samoa, Guam and Northern Mariana Islands and U.S. Virgin Islands, the Median Years are still based on the Hazus 5.1 data since the ACS 2020 data was not yet available for those areas.

The benchmark years are based on a review of online resources, including information from the International Code Council's Building Code Assessment Project, as well as the Earthquake Engineering Research Institute and the Western States Seismic Policy Council. Since benchmark years represent a combination of considerations regarding adoption, implementation and enforcement were also used in selecting the default design levels summarized in Table 5-36. This approach better distributes structures in older areas to lower seismic designs rather than randomly assigning seismic design levels across the state regardless of when the structures were built. Also, the vertical Occupancy to EQ Specific Building Type mapping scheme was previously adopted from the Hazus 4.0 Puerto Rico Earthquake Building Type Mapping Scheme and provided as a new State Database table (*tsSOccupSBTPct*) for each Pacific Territory.

Table 5-35 Estimated Benchmark Year Tsunami Seismic Design Levels for States and Territories

State/Territory	Pre-Code[1] (PC)	Low Code (LC)	Moderate Code (MC)	High Code (HC)	Special High-Code (HS)
Alaska	≤ 1964	1965-1994	1995-2000	≥ 2001	NA
California	≤ 1940	1941-1975	1976-1994	1995-2000	≥ 2001
Hawaii	≤ 1974	1975-1994	1995-2000	≥ 2001	NA
Oregon	≤ 1974	1975-1994	1995-2000	≥ 2001	NA
Washington	≤ 1955	1956-1974	1975-2003	≥ 2004	NA
Puerto Rico	≤ 1974	1975-1994	1995-2005	≥ 2006	NA

State/Territory	Pre-Code[1] (PC)	Low Code (LC)	Moderate Code (MC)	High Code (HC)	Special High-Code (HS)
U.S. Virgin Islands	≤ 1974	1975-2005	≥ 2006	NA	NA
Northern Mariana Islands	≤ 1974	1975-2005	≥ 2006	NA	NA
Guam	≤ 1974	1975-2005	≥ 2006	NA	NA
American Samoa	≤ 1974	1975-2005	≥ 2006	NA	NA

[1]W1 in California coastal counties will be at least Moderate Code (no Pre-Code or Low Code W1, per Hazus Earthquake Model Technical Guidance) and Low Code (no Pre-Code W1) in other states.

Several reclassifications from the original USACE NSI 2022 data for the Exterior Wall Type field were completed to better align with the Hazus General and Earthquake Specific Building Types, based on seismic design and common approaches in the earthquake engineering community:

- Parcel Exterior Wall Value block (D) and concrete block (G) (P_EXTWALL = D or G) are reclassified to Masonry (M) since block and concrete block are considered masonry and not concrete for the purpose of seismic design.

- Since unreinforced masonry is not allowed in high seismic areas, Parcel Exterior Wall Value B (Brick) will be assumed to be veneers over wood frame post-1940 in California and post-1974 for all other Tsunami states. Where P_EXTWALL = 'B' AND EXTWALL = 'M' AND YRBUILT >1974 the EXTWALL types was reclassified to W. SQFT > 5,000 was used to assign W2 vs W1 when smaller.

- All RES2 occupancy types were reclassified to EXTWALL = H (manufactured housing)

5.8.2 Flood-Derived Characteristics

Tsunami Model data include fields related to First Floor Height (FirstFloorHt), which is equivalent to FFHAG in the Flood Model, and Foundation Type (FoundTypeId). These attributes are interrelated since the First Floor Height is directly related to the Flood Foundation Type. It includes a Foundation Type ID and the corresponding First Floor Height based on the Flood Model for evaluation of tsunami inundation depth in the structure.

5.9 Demographics

The demographic data in Hazus is developed from the 2020 Decennial and ACS Census data, with day and night, education K-12, commercial and industrial occupancy estimates from NSI 2022, and college populations from the HIFLD Open Data (2022). The population Census data describes the characteristics of the population and households, including age, income, housing, and ethnic origin among others. The population information is aggregated to a Census block- and tract-level. The Census data are used to estimate direct social loss including displaced households, public shelter needs to estimate casualties due to earthquakes and tsunamis. Table 5-37 describes the input data used.

Table 5-36 Demographics Input Data

Hazus 6.0 Dataset Name	Hazus 6.0 Dataset Date	Hazus 6.0 Dataset Source	Description of Hazus 6.0 Dataset	Geographic Coverage	Previous Data Source (Hazus 5.1)
Decennial Data	2020	U.S. Census Bureau	Census block TIGER Data: Population, Households, Race, Group Quarters, Vacancy	CONUS, AK, HI, PR	U.S. Census 2010 Decennial Data
ACS Data	2020	U.S. Census Bureau	Census block Group TIGER Data: Age and Sex, Income, Ownership, Year Built, Average Value	CONUS, AK, HI, PR	U.S. Census 2010 ACS Data
Decennial Island Data	2020	U.S. Census Bureau	Census Village TIGER Data: Population, Households, Race, Group Quarters, Vacancy	AS, GU, MP, VI	U.S. Census 2010 (Tracts), 2014 gridded Landscan population data.
NSI 2022	June 2022	USACE	Points: Population Locations, Employees, School Enrollment K-12	AK, HI, CONUS except DC	NSI 1.0
DC Data	June 2022	FEMA NHRAP	Dataset developed from Open Data DC due to the lack of Lightbox Parcel Data for DC.	DC	2010 Census and 2006 Dun & Bradstreet
Hazus College & University (EDU2) database	May 2022	Hazus Program Generated	Points: EDU2 Enrollment. Generated from 2022 HIFLD Open data and 2019 hzTract	All U.S.	U.S. Census Bureau
VI Data	July 2019	FEMA NHRAP	Polygon and point data of VI structures, Income Ratios, and additional attributes	VI	PDC grids 2014 (Landscan)
AS, GU and MP PDC (Pacific Disaster Center) Point Data	2014	PDC grids 2014 (Landscan)	Points: Population Locations, Employees, School Enrollment K-12	AS, GU, MP	PDC grids 2014 (Landscan)
NSI 1.0	2017	USACE	Points: Population Locations	AS, GU, MP	U.S. Census 2010 and NSI 1.0

The Census data were processed for all Census blocks and 62 fields of direct importance to the methodology were extracted and integrated into Hazus. These relevant fields are shown in Table 5-38 and are used as part of the modeling for the modules listed in the columns. For example, many of the household unit sub-counts are used as part of the calculations for General Building Stock data by specific occupancy types. For the EQ, HU and FL shelter modules it should be noted that by default race is no longer considered and only the income categories are utilized.

Table 5-37 Demographics Data and Module Utilization Within Hazus

Description of Field	Shelter	Casualty	Occupancy Types	Transportation and Utility Systems
Total Population in Census Block	*	*		*
Total Household in Census Block	*			*
Total # of Males and Females < 18 years old	*	*		
Total # of Males and Females 18-64 years old	*	*		
Total # of Males and Females > 64 years old	*	*		
Total # of People – White	*			
Total # of People – Black	*			
Total # of People – Native American	*			
Total # of People – Asian	*			
Total # of People – Hispanic	*			
Total # of Households with Income < $10,000	*			
Total # of Households with Income $10 - $20k	*			
Total # of Households with Income $20 - $30k	*			
Total # of Households with Income $30 - $40k	*			
Total # of Households with Income $40 - $50k	*			
Total # of Households with Income $50 - $60k	*			
Total # of Households with Income $60 - $75k	*			
Total # of Households with Income $75 - $100k	*			
Total # of Households with Income > $100,000	*			
Total in Residential Population during Day		*		
Total in Residential Population at Night		*		
Hotel Population		*		
Visitor Population		*		
Total Working Population in Commercial Industry		*		
Total Working Population in Industrial Industry		*		
Total Commuting at 5 PM		*		
Total Owner Occupied - Single Household Units	*		*	
Total Owner Occupied - Multi-Household Units	*		*	
Total Owner Occupied - Multi-Household Structure	*		*	
Total Owner Occupied - Mobile Homes	*		*	
Total Renter Occupied - Single Household Units	*		*	

Description of Field	Shelter	Casualty	Occupancy Types	Transportation and Utility Systems
Total Renter Occupied - Multi-Household Units	*		*	
Total Renter Occupied - Multi-Household Structure	*		*	
Total Renter Occupied - Mobile Homes	*		*	
Total Vacant - Single Household Units			*	
Total Vacant - Multi-Household Units			*	
Total Vacant - Multi-Household Structure			*	
Total Vacant - Mobile Homes			*	
School Enrollment K to 12		*		
School Enrollment College		*		

The only Census data available for most of the U.S. Territories was the village-level population and household data. Since the detailed Census data was not yet available for most of the U.S. Territories, a different methodology was required.

For the states, District of Columbia, and Puerto Rico, the formatted 2020 Census data was downloaded with permission from the Integrated Public Use Series (IPUMS) National Historical Geographic Information System (NHGIS) website to aid in the conversion from tabular data to GIS data. The U.S. Census Decennial data was downloaded for the population, households, racial and ethnicity categories, and number of vacant buildings. This data was provided at the Census block level. The U.S. Census ACS data was downloaded for the income levels, owner and renter occupied categories, commuting numbers, year-built categories, median year built, average rent, and average value. This data was provided at the Census-block group level and had to be downscaled to the block level using the block population/block group population and the block households/block group households. Tracts and Blocks with missing median year-built values that had households in year-built categories typically by decade was updated based on the year-built distribution. In some cases, if data from both sources are missing, a block may have a Median year Built date of 0. For example, if there was a Census block with a median year-built of zero and it had three households in it, one built between 1970-1979, one built between 1980 and 1989, and one built between 1990 and 1999, the median year built would be 1985.

The median income data were developed from ACS data at the block group level and downscaled to Census blocks. An additional step was performed to estimate an Income Ratio for each block by dividing the block-level median income by the median income for each state in 2020 inflation adjusted dollars (Table 5-39). These Income Ratios are used in the RES1 replacement cost model.

Table 5-38 Median Household Income by State and Territory

State/Territory	Median Household Income
Alabama	$52,035
Alaska	$77,790
Arizona	$61,529

State/Territory	Median Household Income
Arkansas	$49,475
California	$78,672
Colorado	$75,231
Connecticut	$79,855
Delaware	$69,110
District of Columbia	$90,842
Florida	$57,703
Georgia	$61,224
Hawaii	$83,173
Idaho	$58,915
Illinois	$68,428
Indiana	$58,235
Iowa	$61,836
Kansas	$61,091
Kentucky	$52,238
Louisiana	$50,800
Maine	$59,489
Maryland	$87,063
Massachusetts	$84,385
Michigan	$59,234
Minnesota	$73,382
Mississippi	$46,511
Missouri	$57,290
Montana	$56,539
Nebraska	$63,015
Nevada	$62,043
New Hampshire	$77,923
New Jersey	$85,245
New Mexico	$51,243
New York	$71,117
North Carolina	$56,642
North Dakota	$65,315
Ohio	$58,116
Oklahoma	$53,840
Oregon	$65,667
Pennsylvania	$63,627
Rhode Island	$70,305
South Carolina	$54,864

State/Territory	Median Household Income
South Dakota	$59,896
Tennessee	$54,833
Texas	$63,826
Utah	$74,197
Vermont	$63,477
Virginia	$76,398
Washington	$77,006
West Virginia	$48,037
Wisconsin	$63,293
Wyoming	$65,304
Puerto Rico	$21,058

The NSI 2022 dataset was used to populate the estimates of residential and nighttime population, commercial and industrial working employees, hotel population, and K through 12 school population. The HIFLD Open dataset was used to estimate the college/university population. The site-specific data were aggregated to the Census block- and tract-levels.

For American Samoa, Northern Mariana Islands, Guam, and the U.S. Virgin Islands, the village-level Census population and household data was downscaled to the Census block-level using the NSI data (NSI 1.0 for American Samoa, Northern Mariana Islands, and Guam and NSI 2022 for U.S. Virgin Islands), specifically the residential square footage was used to downscale the village-level data. In areas where there was a population and no residential square footage, the total building square footage was used. HIFLD Open data was used for college/university enrollment for all four territories. NSI 1.0 (FEMA, 2021b), a site-specific dataset, was used to populate the residential and nighttime population numbers, commercial and industrial working employee numbers, hotel population, and K through 12 school enrollment numbers for American Samoa, Northern Mariana Islands, and Guam. These numbers were scaled using the new population and household values at the Census block level. U.S. Virgin Islands used the NSI 2022 except for enrollment which was scaled using the 2010 data and new population numbers due to a limitation in the 2022 data. For the other demographic fields, the 2010 data was scaled using the 2020 Census population and household numbers.

For the NSI 2022 data, the population estimates for each NSI structure were developed by USACE from the U.S. Census Bureau's LEHD data. The LEHD program produces several datasets, including Quarterly Workforce Indicators and the LEHD Origin-Destination Employment Statistics. These statistics, which can be useful for consequence modeling, provides employment statistics, including worker counts, linking residence and work locations at the Census block level. The LEHD method of population assignment uses four population pools: working population and residential population, day, and night. Census 2020 population data are used to approximate the total residential population of a Census block. The LEHD dataset is then used to identify the nonresidential population of the block, as well as model the movement of population from residential structures into nonresidential. Section 5.8 provides more information about estimation of these values.

5.10 Flood-Specific Inventory Data for Vehicles

Vehicles are no longer available for analysis in the Hazus Flood Model; however, they can be modeled in the Flood Model when data is provided by the user. Significant customization is required to update parameters to account for these changes, so it is recommended that interested users contact the Hazus Help Desk (see Section 1.5).

Section 6. General Building Stock: Baseline Database for Economic Values

The final all hazard General Building Stock data type covered in this manual are economic values, which are used for loss calculations in Hazus. The specific economic data types to be covered include Structure Replacement Value, Contents Replacement Value, and Other Economic Values, such as other primary economic values used by more than one hazard, including business inventory value, and disruption impacts to individuals and businesses from relocation, and losses of different types of income.

Table 6-1 summarizes these major GBS economic values by data type, hazard, sources and geographic coverage.

Table 6-1 General Building Stock Economic Data Summary

Hazus 6.0 Dataset Name	Hazus 6.0 Dataset Date	Hazus 6.0 Dataset Source	Description of Hazus 6.0 Dataset	Geographic Coverage	Previous Data Source (Hazus 5.1)
NSI 2022	June 2022	USACE	Point-based structure inventories. Developed from Lightbox Parcel, NGA lidar, USA Structures and Bing footprints.	AK, HI, CONUS except DC	2010 Census and 2006 Dun & Bradstreet
DC Data	June 2022	FEMA NHRAP	Dataset developed from Open Data DC due to the lack of Lightbox Parcel Data for DC.	DC	NSI 1.0
Hazus College & University (EDU2) database	May 2022	Hazus Program Generated	Created from: 2022 HIFLD Open data, 2019 hzTract, 2022 hzMeansCountyLocationFactor (see Section 6.3) and 2022 College and University Replacement Cost Model (see Section 7.2.5.3.) Provides structure level EDU2 data. The number of students field to use is 'NumStudents. This file is used to replace the NSI 2022 EDU2 data.	All U.S.	2010 Census, 2006 Dun & Bradstreet, and NSI 1.0 (for Tsunami GBS only)
Income Ratios	June 2022	Hazus Program Generated	Income ratios developed from Census data. Calculated using the block group median income divided by state median income.	CONUS, AK, HI, PR[1]	U.S. Census Bureau

Hazus 6.0 Dataset Name	Hazus 6.0 Dataset Date	Hazus 6.0 Dataset Source	Description of Hazus 6.0 Dataset	Geographic Coverage	Previous Data Source (Hazus 5.1)
PR Data	2019	FEMA NHRAP	Polygon and point data of PR structures, occupancy types.	PR	U.S. Census Bureau
VI Data	July 2019	FEMA NHRAP	Polygon and point data of VI structures, Income Ratios, and additional attributes.	VI	U.S. Census Bureau and Landscan
Hazus Replacement Cost Model and other Economic Models	2022[2]	Hazus Program Generated	Replacement cost derived values to calculate the valuation of structures and content, models for commercial inventory value and business interruption loss parameters (rent, relocation, income and wages). Uses data from U.S. Census 2020 Manufactured Housing Survey Annual Data (for RES2), BEA (2022a and b) and BLS (2022).	CONUS, AK, HI, U.S. Territories	2018 Replacement Cost Methodology

[1]No income ratio data were available for the Pacific Territories (AS, GU, MP).
[2]All structure replacement values based on 2022 replacement value model except RES2 (2020 Manufactured Housing Survey Annual Data).

6.1 Structure Replacement Value

Structure replacement cost models within Hazus are derived from industry-standard cost-estimation models. The valuation included an adjustment to the square footage value based on county adjustment factors using CountyLocationFactor for all Residential and non-residential occupancy types. For manufactured housing (RES2) regional Census valuations are used.

Replacement cost data are stored within Hazus at the Census tract and Census block level for each occupancy class. For each Hazus occupancy class, a default structure full replacement cost model (cost per square foot) has been determined and is provided in Table 6-2. It should be noted that the replacement costs provided in Table 6-2 Default Full Structure Replacement Cost are an average replacement cost by occupancy. Commercial and industrial occupancies have a typical building replacement cost model associated with each occupancy class (e.g., COM4, Professional/Technical/Business Services, is represented by a typical, 80,000 square feet, 5 to 10 story office building). Building area (given as square footage) costs presented in the table represent an average from the various alternatives for exterior wall construction (wood siding over wood frame, brick veneer over wood frame, concrete block over wood joists, etc.). For non-residential structures, the default configuration assumes structures without basements.

Table 6-2 Default Full Structure Replacement Cost

Specific Occupancy	Model Description	Structure Replacement Cost/ft^2 (2022)
RES1	See Table 6-3 Replacement Costs for RES1 Structures	See Table 6-3 Replacement Costs for RES1 Structures
RES2	U.S. Census Bureau 2020 Manufactured Housing Survey Annual Data, see Table 6-6 Manufactured Housing Replacement Cost Model	See Table 6-6 Manufactured Housing Replacement Cost Model
RES3A	Modified Single Family Home, 2,200 ft^2	$134.57
RES3B	Modified Single Family Home, 4,400 ft^2	$118.30
RES3C	Apartment, low-rise, 8,000 ft^2	$250.19
RES3D	Apartment, low-rise, 15,000 ft^2	$232.69
RES3E	Apartment, mid-rise, 40,000 ft^2	$217.05
RES3F	Apartment, mid-rise, 80,000 ft^2	$198.83
RES4	Hotel, mid-rise, 135,000 ft^2	$204.58
RES5	College Dorm, low-rise, 25,000 ft^2	$225.12
RES6	Nursing Home, low-rise, 25,000 ft^2	$261.45
COM1	Store, Dept., 110,000 ft^2	$133.61
COM2	Warehouse, 30,000 ft^2	$135.47
COM3	Garage, Repair, 10,000 ft^2	$162.58
COM4	Office, mid- to high-rise, 80,000 ft^2	$204.43
COM5	Bank, 4,100 ft^2	$303.88
COM6	Hospital, low-rise, 55,000 ft^2	$392.76
COM7	Medical office, low-rise, 7,000 ft^2	$279.38
COM8	Restaurant, 5,000 ft^2	$259.48
COM9	Movie Theatre, 12,000 ft^2	$213.33
COM10	Parking Garage, mid-rise, 145,000 ft^2	$93.88
IND1	Factory, 30,000 ft^2	$162.65
IND2	Warehouse, 30,000 ft^2	$135.47
IND3	College Lab, 45,000 ft^2	$230.43
IND4	College Lab, 45,000 ft^2	$230.43
IND5	College Lab, 45,000 ft^2	$230.43
IND6	Warehouse, 30,000 ft^2	$135.47
AGR1	Warehouse, 30,000 ft^2	$135.47
REL1	Church, 17,000 ft^2	$222.10
GOV1	Town Hall, 11,000 ft^2	$174.35
GOV2	Police Station, low-rise 11,000 ft^2	$284.46
EDU1	High School, 130,000 ft^2	$237.73
EDU2	College Classroom, low-rise, 50,000 ft^2	$197.10

The RES1 (single-family residential) replacement cost model considers the cost of the main structure, as well as additional costs associated with basements and garages. The adjustments for basements consider construction classes (Economy, Average, Custom, and Luxury) and number of stories. Table 6-3 provides replacement costs for the various single-family dwelling configurations available in the baseline building inventory (One-, Two-, and Three-story and split level), assuming a typical size of 1,800 square feet. The 1,800 square foot value was selected during Hazus Flood Model development as a representative national value, based on available data. Costs represent an average for the various alternatives for exterior wall construction.

Table 6-3 Replacement Costs for RES1 Structures

Construction Class	Height Class	2022 Average cost per ft² for RES1 with No Basement	2022 Average cost per ft² for RES1 with Finished Basement	2022 Average cost per ft² for RES1 with Unfinished Basement
Economy	One-story	$114.63	$148.48	$125.03
Economy	Two-story	$121.00	$139.95	$127.75
Economy	Three-story	$121.00	$139.95	$127.75
Economy	Split level	$111.49	$130.44	$118.24
Average	One-story	$128.20	$168.75	$140.95
Average	Two-story	$132.88	$158.08	$140.98
Average	Three-story	$137.43	$156.88	$143.73
Average	Split level	$122.86	$148.06	$130.96
Custom	One-story	$172.73	$234.63	$196.98
Custom	Two-story	$174.96	$210.21	$189.21
Custom	Three-story	$179.34	$204.94	$189.84
Custom	Split level	$162.83	$198.08	$177.08
Luxury	One-story	$209.44	$274.34	$234.29
Luxury	Two-story	$212.86	$250.56	$227.86
Luxury	Three-story	$218.28	$245.93	$229.53
Luxury	Split level	$197.95	$235.65	$212.95

Because the Flood Model default single-family residential (SFR) damage model is based on past FEMA damage functions, whose coverage extends to garages, the replacement cost of garages is included in the basic replacement cost. Relevant models for SFR garages include costs by construction class (Economy, Average, Custom, and Luxury), for detached and attached one-car, two-car and three-car garages, constructed of wood or masonry. For incorporation into Hazus, costs by size and construction class have been averaged for attached/detached and various materials. Average costs associated with garage types included in the default inventory for single-family residential structures (one-car, two-car, and three-car) are provided in Table 6-4.

Table 6-4 Single-Family Residential Garage Adjustment

Construction Class	Garage Type	Average Additional Garage Cost per Residence (2022)
Economy	One-car	$19,394
Economy	Two-car	$30,397
Economy	Three-car	$41,125
Average	One-car	$20,313
Average	Two-car	$31,600
Average	Three-car	$42,613
Custom	One-car	$22,377
Custom	Two-car	$35,519
Custom	Three-car	$48,307
Luxury	One-car	$28,233
Luxury	Two-car	$44,515
Luxury	Three-car	$60,444

Weighting factors for the construction class for the given Census block (also used in the replacement value calculations) are shown in Table 6-5.

Table 6-5 RES1 Construction Class Weights Relative to Income Ratio

Income Ratio[1], [2]	Luxury	Custom	Average	Economy
IR < 0.5	-	-	-	100
0.5 <= IR < 0.85	-	-	25	75
0.85 <= IR < 1.25	-	25	75	-
1.25 <= IR < 2.0	-	100	-	-
IR <= 2.0	100	-	-	-

[1]Income Ratio (IR) is calculated as the Census block group median household income divided by the state median household income.
[2]No Income Ratio data were available for the Pacific Territories (AS, GU, and MP); the Average construction class has been assumed.

RES2 specific occupancy is designated for manufactured housing, which represents mobile homes, but not single-family pre-manufactured housing. Structure replacement values for RES2 structures, based on U.S. Census 2020 Manufactured Housing Survey Annual Data, are provided in Table 6-6.

Table 6-6 Manufactured Housing Replacement Cost Model

Census Region[1]	Cost per Square Foot (2020)[2]
Northeast	$68.65
Midwest	$59.14
South	$55.97
West	$73.92

[1]Census region list of states and territories provided in Table 3-1.
[2]All replacement cost values based on U.S. Census Bureau 2020 Manufactured Housing Survey Annual Data.

For the Hurricane Model, specifically related to surge modeling, Hazus further subdivides the overall building replacement value into individual subassemblies such as foundation or roof. This supports the ability of the model to properly account for damages from both flood and wind damages from hurricane events. See the *Hazus Hurricane Model Technical Manual* (FEMA, 2024b) for more details on subassembly replacement values.

6.1.1 RES1 Valuation Equation

Equation 6-1 is used to develop the valuation for individual single-family residential buildings, aggregated at the Census block level for the Flood model and to the Census tract level for the Earthquake and Hurricane models. Where available, NSI 2022 data on basements (including whether basements are finished or unfinished) and number of stories are used directly to estimate associated replacement costs for individual buildings[3]. When NSI 2022 or similar data are not available, the original Hazus distributions by Census Region and Division are utilized. None of the available data sources provided sufficient information on garage type, so the original Hazus garage distributions by Census Region (Table 5-5) were used.

The source data for the U.S. Virgin Islands included the number of stories and basement information, however, in the U.S. Virgin Islands the basement attribution often represents cisterns, so while the number of stories data could be used directly, the regional basement factors were applied.

The District of Columbia and Puerto Rico source data were missing key attributes. The DC data did not contain basement attributes but did contain number of stories and were all 3 or above. The PR data had neither basement nor number of stories attributes. In these cases, the regional Census distributions available for all Hazus states were used.

Data availability is summarized in Table 6-7, and the RES1 regional basement and number of stories distributions are provided in Table 6-8 and Table 6-9, respectively.

Table 6-7 RES1 Valuation Model Data Sources

Geographic Area	Number of Stories	Basement	Garage
CONUS (except District of Columbia), Alaska, Hawaii	NSI 2022	NSI 2022	Distribution by Census Region[2]
U.S. Virgin Islands	VI Data[3]	VI Data[3]	Distribution by Census Region[2]
American Samoa, Guam, Northern Mariana Islands	AS, GU, MP Data[4]	AS, GU, MP Data[4]	Distribution by Census Region[2]
District of Columbia	Open Data DC[5]	Distribution by Census Division[6]	Distribution by Census Region[2]

[3] There was one anomalous RES1 replacement cost value for a single structure in Cherokee County, SC that was removed to reduce the overall RES1 Census Block replacement cost to a reasonable value. For more information and frequently asked questions regarding the NSI database, please visit https://www.hec.usace.army.mil/confluence/nsi/technicalreferences/latest/frequently-asked-questions.

Geographic Area	Number of Stories	Basement	Garage
Puerto Rico	Distribution by Census Region[7]	Distribution by Census Division[6]	Distribution by Census Region[2]

[1]All RES1 in AS, GU and MP assumed to have no basement
[2]Table 5-5
[3]FEMA NHRAP, 2019
[4]FEMA NHRAP, 2022 see Section 3.7 and 5.8
[5]FEMA NHRAP, 2022 see Section 3.6
[6]Table 6-8
[7]Table 6-9

Table 6-8 Basement Distribution by Census Division

Census Division[1]	Percent with Basement[2]	Percent without Basement
New England	72%	28%
Middle Atlantic	58%	42%
East North Central	57%	42%
West North Central	56%	44%
South Atlantic	19%	81%
East South Central	18%	82%
West South Central	2%	98%
Mountain	26%	74%
Pacific	8%	92%

[1]Census Division list of states provided in Table 3-1.
[2]Based on U.S. Energy Information Administration (EIA), 2009 Residential Energy Consumption Survey, Final Release April 2013, Structural and Geographic Characteristics of U.S. Homes, by Census Region, and Division.

Table 6-9 Percent Distribution of Number of Stories for Single-family Residences by Census Region

Census Region[1]	One-Story[2]	Two-Story	Three-Story	Split Level
Northeast	25%	68%	5%	2%
Midwest	50%	46%	2%	2%
South	66%	32%	1%	1%
West	66%	30%	2%	2%

[1]Census Region list of states provided in Table 3-1.

[2]Based on EIA, 2009 Residential Energy Consumption Survey, Final Release April 2013, Structural and Geographic Characteristics of U.S. Homes, by Census region.

The RES1 valuation can be summarized mathematically in Equation 6-1:

Equation 6-1 RES1 Valuation Equation

$$V_{RES1,k} = \left(A_{RES1,k}\right) * \left[\sum_{i=1}^{4} \sum_{j=1}^{4} \sum_{l=1}^{3} w_{i,k} * w_{j,k} * w_{l,k} * C_{i,j,l}\right] + \left[\sum_{i=1}^{4} \sum_{m=1}^{4} w_{i,k} * w_{m,k} * C_{i,m}\right]$$

Where:

k	Census block in which the RES1 building is located.
$V_{RES1,k}$	the estimated valuation for the single-family residences (RES1) being evaluated, located in Census block (k) prior to the application of location factors.
$A_{RES1,k}$	the single-family residential (RES1) building area (square feet) taken from the NSI 2022 (or equivalent) data set, for the building located in Census block k.
i	the construction class or classes (1 = Economy, 2 = Average, 3 = Custom, 4 = Luxury) of the building being evaluated, determined from the Census block's income ratio relative to the ranges provided in Table 6-5 RES1 Construction Class Weights Relative to Income Ratio.
$w_{i,k}$	the weighting factor for the construction class or classes (i) for the building's Census block (k) provided in Table 6-5 RES1 Construction Class Weights Relative to Income Ratio.
j	the number of stories class for the single-family (RES1) structure being evaluated (1 = One-story, 2 = Two-story, 3 = Three-story, and 4 = split level).
$w_{j,k}$	the weighting factor for the number of stories class (j) for the building located in Census block (k), depending on the Census region of that block (by state FIPS). Weighting factors were developed from regional construction distributions as provided in Table 6-9.
l	the basement status for the single-family residence being evaluated (1 = no basement, 2 = unfinished basement, 3 = finished basement).
$w_{l,k}$	the weighting factor for basements in the building's Census block (k) depending on the Census Division of that block (by state FIPS). When this weighting factor is used, l varies from 1 (no basement) to 2 (basement assumed unfinished); l=3 (finished basement) is not considered. Weighting factors were developed from regional foundation type distributions provided in Table 6-8.
$C_{i,j,l}$	the cost per square foot of the structure, for the given construction class (i), number of stories class (j), and basement type (l), as provided in Table 6-3 Replacement Costs for RES1 Structures.
m	the garage type for the single-family residence being evaluated (1 = 1-car, 2 = 2-car, 3 = 3-car, 4 = carport, and 5 = none).

$w_{m,k}$ — the weighting factor for the garage type (m) for the building's Census block (k) depending on the Census region of that block (by state FIPS). Weighting factors were developed from regional garage distributions provided in Table 5-5.

$C_{i,m}$ — the additional replacement cost for a given garage type (m), for the given construction class (i) as shown in Table 6-4. Note: $C_{i,m}$ = 0 when m = 4 (carport) or m = 5 (none).

As Equation 6-1 shows, the basic replacement cost per square foot is a function of the construction class, the number of stories, and the presence and type of basement and garage.

6.1.2 RES2 Valuation Equation

RES2 square footage is taken directly from NSI building data, aggregated to the Census block and tract. Unlike RES1 occupancy classifications, there are no allowances for variation of floor heights (number of stories) or other valuation parameters. The valuation of manufactured housing is the straight multiplication of each building's floor area by the default replacement cost per square foot, which varies by Census region rather than state or county. The cost per square foot for each Census region is developed from the U.S. Census 2020 Manufactured Housing Survey Annual Data (latest available) on average square feet of floor area is provided in Table 6-6 Manufactured Housing Replacement Cost Model.

The calculation for manufactured housing is defined in Equation 6-2:

Equation 6-2 RES2 Valuation Equation

$$V_{RES2\,,k} = A_{RES2\,,k} * C_{RES2}$$

Where:

k — Census block in which the RES2 building is located.

$V_{RES2,k}$ — the estimated valuation for the Manufactured Housing (RES2) being evaluated, located in Census block (k).

$A_{RES2,k}$ — the Manufactured Housing (RES2) floor area (square feet) taken from the NSI 2022 (or equivalent) data set, for the building located in Census block (k).

C_{RES2} — the Manufactured Housing (RES2) cost per square foot. RES2 replacement costs by Census region area provided in Table 6-6 Manufactured Housing Replacement Cost Model.

6.1.3 Other Occupancies Valuation Equation

The equation for the remaining residential occupancies (RES3-RES6) and all non-residential (COM, IND, EDU, REL, GOV, and AGR) occupancies is not as complex as the single-family model. The replacement cost is averaged across structure types, stories, and construction classes.

Equation 6-3 applies to the remaining residential occupancies and non-residential occupancies.

Equation 6-3 Other Occupancies Valuation Equation

$$V_{x.k} = A_{x,k} * C_x$$

Where:

k	Census block in which the building is located.
x	defines the remaining occupancy classifications for the remaining occupancies (i.e., RES5, COM1, REL1, etc.) for which the cost is being calculated.
$V_{x,k}$	the estimated valuation for the specific occupancy (x) (such as RES4, COM3, or IND6) being evaluated, located in Census block (k), prior to application of location factors.
$A_{x,k}$	the floor area (square feet) for a specific occupancy (x) (such as RES3, COM8, IND4, GOV1, etc.) taken from the NSI 2022 (or equivalent) data set, for the building located in Census block (k).
C_x	the cost per square foot for the specific occupancy (x). The replacement costs are provided in Table 6-2 Default Full Structure Replacement Cost by specific occupancy.

6.2 Contents Replacement Value

Contents replacement value was estimated as a percent of structure replacement value as part of the original development of Hazus by the National Institute of Building Sciences (NIBS) in 1999. Table 6-10 summarizes these values for all Hazus specific occupancies.

Table 6-10 Baseline Hazus Contents Value as Percent of Structure Value

Label	Contents Value (%)
RES1	50%
RES2	50%
RES3A-F	50%
RES4	50%
RES5	50%
RES6	50%

Label	Contents Value (%)
COM1	100%
COM2	100%
COM3	100%
COM4	100%
COM5	100%
COM6	150%
COM7	150%
COM8	100%
COM9	100%
COM10	50%
IND1	150%
IND2	150%
IND3	150%
IND4	150%
IND5	150%
IND6	100%
AGR1	100%
REL1	100%
GOV1	100%
GOV2	150%
EDU1	100%
EDU2	150%

6.3 County Modification Factors

The replacement value model tables provide average national costs. With the exception of costs for manufactured housing (RES2), the national costs are localized by application of population-weighted residential and non-residential location factors that are provided with Hazus for counties and states throughout the U.S., as well as for the U.S. Territories. The residential modification factor is applied to RES1 only, and the non-residential county modification factors are applied to all other Occupancies including RES3-6. These factors were applied in the development of GBS data for structure replacement values that are tabulated in the Hazus databases (i.e., SQL tables hzExposureOccupB and hzExposureOccupT). The modification factors by County are available in each inventory database in the SQL table hzMeansCountyLocationFactor.

6.4 Depreciated Building Replacement Values

The depreciation models utilized in the Flood Model were based on industry-standard depreciation methods. The depreciation age in Hazus is estimated based on the computer clock minus the Median Year Built as developed in the Demographic block data. The depreciation models relate building age to expected percent decrease in structure value over time; the depreciation models have not changed significantly since their initial evaluation for use in the Hazus Flood Model. Two depreciation cost models are used in Hazus: one for single-family residential structures and one for commercial/industrial/institutional structures.

6.4.1 Single-Family Residential Occupancy Depreciation Model

The replacement cost model includes three tabular depreciation models for residential structures based on actual structure age and general condition (Good, Average, and Poor). Best-fit lines through the various models are shown graphically in Figure 6-1.

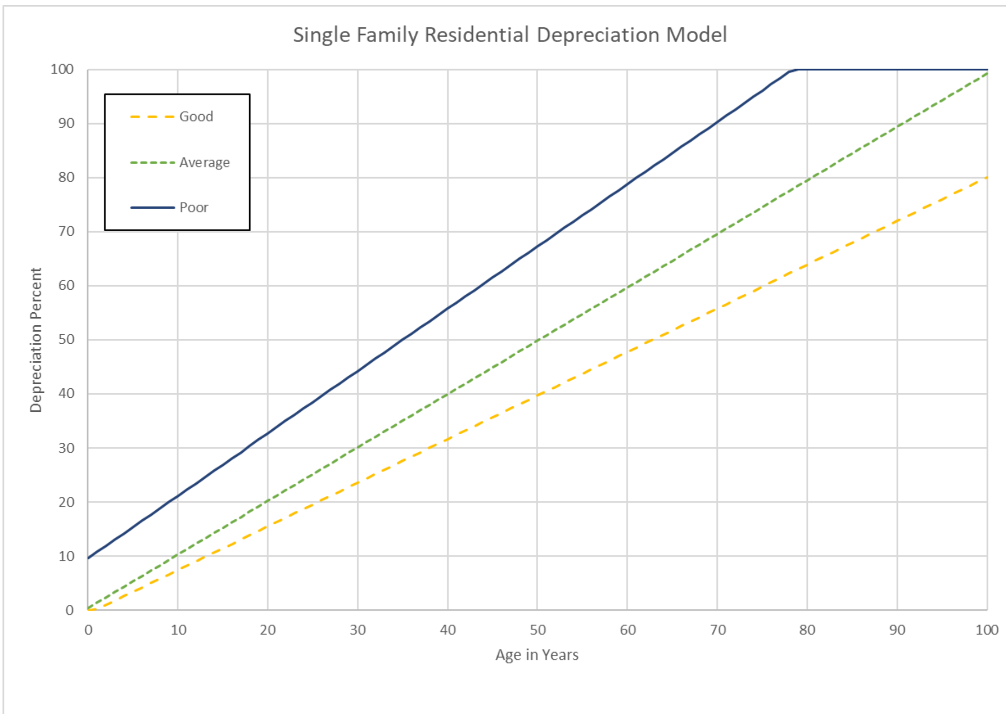


Figure 6-1 Single-Family Residential Depreciation Models

The underlying assumption in the GBC Methodology used in the Flood Model is that for any community, some combination of the full replacement cost models (Economy, Average, Custom, or Luxury), and depreciation models (Good, Average, or Poor) will best represent the true depreciated value. This basic premise was tested during the initial Hazus Flood Model development process on more than 8,000 homes in Grand Forks, ND, more than 160,000 homes in Mecklenburg County, NC, and more than 60,000 homes in Fort Collins, CO. Results indicated that good agreement with assessed (depreciated) value could be attained from the models.

6.4.2 Other Residential and Non-Residential Occupancies Depreciation Model

Unlike the residential depreciation model, the commercial/industrial/institutional depreciation is determined from "observed age" and building framing material (frame, masonry on wood, and masonry on masonry or steel). An average depreciation function has been derived for use in Hazus, as shown in Figure 6-2. The non-residential structure's "observed age" was assumed to reflect the structure's condition (e.g., the observed age should reflect any remodeling or renovation that would reduce deterioration, and therefore decrease the observed age).

It was assumed that chronological age is approximately equivalent to observed age for the non-residential structures, primarily because these structures are less likely to be used far beyond their typical life expectancy. For example, in Grand Forks, ND, many homes are significantly older than the typical life expectancy of about 50 to 60 years, whereas commercial and industrial structures did not demonstrate the same widespread longevity.

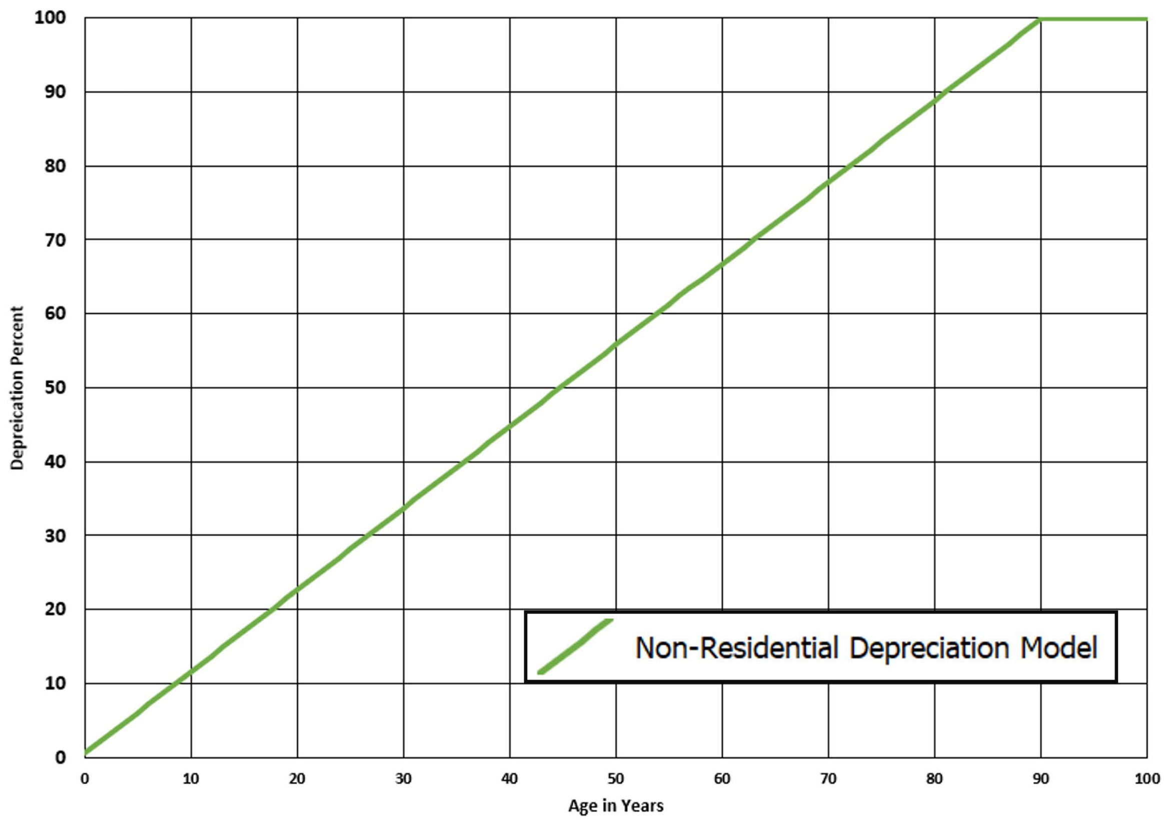


Figure 6-2 Non-Residential Depreciation Model

6.5 Other Economic Values

6.5.1 Business Inventory

For occupancies with inventory considerations (COM1, COM2, IND1 - IND6, and AGR1), inventory losses are estimated using Hazus baseline inventory values. Inventory values are estimated by first estimating annual sales (shown in Table 6-11) and then applying a value from Table 6-12 that represents inventory values as a percentage of annual sales.

Previous updates to the original Hazus annual sales data employed Consumer Price Index (CPI) ratios to update annual sales directly, with output/employment updated from various BLS and BEA data (e.g., BLS "Industry Productivity & Cost" data on Output per Worker by Industry for COM1/COM2, BLS "Major Sector Productivity & Costs" data on Output per Job by Industry for IND1-IND5, and BEA "Output by

Industry" data combined with BLS or BEA data on employment for IND6 and AGR1, respectively). Unfortunately, this update approach severed the intended relationship between sales and output per employee (Sales = Output/Employment divided by Square Foot/Employee), and only the CPI update of annual sales was relevant, as this is the only data actually used in Hazus.

For Hazus 6.0, a more comprehensive approach has been applied. A single, consistent source of data is now used; 2020 (latest available) BEA data on employment by industry (BEA, 2020a) and output by industry BEA (2020b) have been individually mapped to Hazus occupancy classes using the original Hazus Standard Industrial Classification (SIC) code mapping to develop occupancy specific estimates of Output per Employee. These are then divided by the original Hazus estimates of Square Feet per Employee to arrive at Annual Sales (dollars per square foot). The resulting values are, for several of the occupancies (e.g., COM1, AGR1), much larger than the values that would result from the prior update approach but are sourced more consistently and better reflect changes in output and employment over time at the industry level. Table 6-11 reflects the updated 2020 economic values.

Table 6-11 Annual Gross Sales or Production

Hazus Specific Occupancy Class	Class Description	Output/ Employment (2020)	Square Feet Floor Space (ft^2/Employee)[1]	Annual Sales (2020, $/$ft^2$)
COM1	Retail Trade	$603,863	825	$732
COM2	Wholesale Trade	$367,681	900	$409
IND1	Heavy	$390,894	550	$711
IND2	Light	$286,005	590	$485
IND3	Food/Drugs/Chemicals	$752,420	540	$1,393
IND4	Metals/Minerals Processing	$707,640	730	$969
IND5	High Technology	$357,170	300	$1,191
IND6	Construction	$240,994	250	$964
AGR1	Agriculture	$327,606	250	$1,310

[1]Values from original development of Hazus by NIBS in 1999.

Table 6-12 Business Inventory (Percent of Gross Annual Sales)

Label	Occupancy Class	Business Inventory (%)[1]
COM1	Retail Trade	13%
COM2	Wholesale Trade	10%
IND1	Heavy	5%
IND2	Light	4%
IND3	Food/Drugs/Chemicals	5%
IND4	Metals/Minerals Processing	3%
IND5	High Technology	4%
IND6	Construction	2%
AGR1	Agriculture	8%

[1]*Values from original development of Hazus by NIBS in 1999.*

6.5.2 Relocation Expenses (Rental and Disruption Costs)

Relocation expenses represent disruption costs to building owners for selected occupancies. These include all occupancies except entertainment (COM8), theaters (COM9), parking facilities (COM10), and heavy industry (IND1). Expenses contain disruption costs that include the cost of shifting and transferring, and the rental of temporary space. These costs are incurred once the building reaches a damage state of “Slight” or greater. By default, no threshold is applied in the Flood Model.

Table 6-13 shows the 2021 values for rental and disruption costs. It should be noted the default values for rental costs and disruption costs provided in Table 6-13 have been updated from the original development year of 1994 to the year 2021 using a ratio of the annual CPI. The original dollar value was multiplied by the ratio of the CPI value for the current year to the CPI value for the year the data were developed. Annual CPI data for the years 1990 through 2021 are provided in Table 6-14. The rental costs in Table 6-13 are also used in Hazus loss calculations where rent is considered a source of business income, relying on information on the percent of owner occupation as shown in Table 6-15.

Table 6-13 Rental Costs and Disruption Costs

Label	Occupancy Class	Rental Cost (2021) ($/ft^2 /month) [1]	Rental Cost (2021) ($/ft^2 /day)	Disruption Costs (2021) ($/ft^2) [1]
RES1	Single-family Dwelling	0.91	0.030	1.10
RES2	Mobile Home	0.64	0.021	1.10
RES3A	Multi-family Dwelling; Duplex	0.82	0.027	1.10
RES3B	Multi-family Dwelling; Triplex/Quad	0.82	0.027	1.10
RES3C	Multi-family Dwelling; 5–9 units	0.82	0.027	1.10
RES3D	Multi-family Dwelling; 10–19 units	0.82	0.027	1.10
RES3E	Multi-family Dwelling; 20–49 units	0.82	0.027	1.10
RES3F	Multi-family Dwelling; 50+ units	0.82	0.027	1.10

Label	Occupancy Class	Rental Cost (2021) ($/ft² /month) [1]	Rental Cost (2021) ($/ft² /day)	Disruption Costs (2021) ($/ft²) [1]
RES4	Temporary Lodging	2.74	0.091	1.10
RES5	Institutional Dormitory	0.55	0.018	1.10
RES6	Nursing Home	1.01	0.034	1.10
COM1	Retail Trade	1.55	0.052	1.46
COM2	Wholesale Trade	0.64	0.021	1.28
COM3	Personal and Repair Services	1.83	0.061	1.28
COM4	Professional/Technical/ Business Services	1.83	0.061	1.28
COM5	Banks	2.29	0.076	1.28
COM6	Hospital	1.83	0.061	1.83
COM7	Medical Office/Clinic	1.83	0.061	1.83
COM8	Entertainment & Recreation	2.29	0.076	0.00
COM9	Theaters	2.29	0.076	0.00
COM10	Parking	0.46	0.015	0.00
IND1	Heavy	0.27	0.009	0.00
IND2	Light	0.37	0.012	1.28
IND3	Food/Drugs/Chemicals	0.37	0.012	1.28
IND4	Metals/Minerals Processing	0.27	0.009	1.28
IND5	High Technology	0.46	0.015	1.28
IND6	Construction	0.18	0.006	1.28
AGR1	Agriculture	0.91	0.030	0.91
REL1	Church/Membership Organization	1.37	0.046	1.28
GOV1	General Services	1.83	0.061	1.28
GOV2	Emergency Response	1.83	0.061	1.28
EDU1	Schools/Libraries	1.37	0.046	1.28
EDU2	Colleges/Universities	1.83	0.061	1.28

[1]Values adjusted using CPI to 2021 from original values from development of Hazus by NIBS in 1999.

Table 6-14 Consumer Price Index 1990–2021

Year	Annual CPI[1]
1990	130.7
1991	136.2
1992	140.3
1993	144.5
1994	148.2
1995	152.4
1996	156.9

Year	Annual CPI[1]
1997	160.5
1998	163.0
1999	166.6
2000	172.2
2001	177.1
2002	179.9
2003	184.0
2004	188.9
2005	195.3
2006	201.6
2007	207.3
2008	215.3
2009	214.5
2010	218.1
2011	224.9
2012	229.6
2013	233.0
2014	236.7
2015	237.0
2016	240.0
2017	245.1
2018	251.1
2019	255.7
2020	258.8
2021	271.0

[1]Note: As of March 2022. Source is U.S. Bureau of Labor Statistics.

Table 6-15 Percent Owner Occupied by Occupancy Class

Label	Occupancy Class	Percent Owner Occupied[1]
RES1	Single-family Dwelling	75%
RES2	Mobile Home	85%
RES3A	Multi-family Dwelling; Duplex	35%
RES3B	Multi-family Dwelling; Triplex/Quad	35%
RES3C	Multi-family Dwelling; 5–9 units	35%
RES3D	Multi-family Dwelling; 10–19 units	35%
RES3E	Multi-family Dwelling; 20–49 units	35%
RES3F	Multi-family Dwelling; 50+ units	35%
RES4	Temporary Lodging	0%

Label	Occupancy Class	Percent Owner Occupied[1]
RES5	Institutional Dormitory	0%
RES6	Nursing Home	0%
COM1	Retail Trade	55%
COM2	Wholesale Trade	55%
COM3	Personal and Repair Services	55%
COM4	Professional/Technical/Business Services	55%
COM5	Banks	75%
COM6	Hospital	95%
COM7	Medical Office/Clinic	65%
COM8	Entertainment & Recreation	55%
COM9	Theaters	45%
COM10	Parking	25%
IND1	Heavy	75%
IND2	Light	75%
IND3	Food/Drugs/Chemicals	75%
IND4	Metals/Minerals Processing	75%
IND5	High Technology	55%
IND6	Construction	85%
AGR1	Agriculture	95%
REL1	Church/Membership Organization	90%
GOV1	General Services	70%
GOV2	Emergency Response	95%
EDU1	Schools/Libraries	95%
EDU2	Colleges/Universities	90%

[1]Values from original development of Hazus by NIBS in 1999.

6.5.3 Loss of Income

Business activity generates several types of income. First, there is income associated with capital, or property ownership. Business generates profits, and a portion of this is paid out to individuals (as well as to pension funds and other businesses) as dividends, while another portion (retained earnings) is returned to the enterprise. Businesses also make interest payments to banks and bondholders for loans. They pay rent on property and make royalty payments for the use of tangible assets. Those in business for themselves, or in partnerships, generate a category called proprietary income, one portion of which reflects their profits and the other reflects a salary (e.g., the case of lawyers or dentists). Finally, the biggest category of income generated/paid is associated with labor. In most urban regions of the U.S., wage and salary income comprises more than 75% of total personal income payments.

It is possible to link income payments to various physical damage measures, including sales, property values, or building area. Income losses occur when building damage disrupts economic activity. Hazard specific equations for income losses in Hazus include variables for loss of income over time (Table 6-16), and the potential to recapture income (Table 6-17).

Business-related losses from disaster events can be recouped, to some extent, by working overtime after the event. For example, a factory closed for six weeks due to directly caused structural damage or indirectly caused shortage of supplies may work extra shifts in the weeks or months following its reopening.

This ability to recapture production will differ across industries. It will be higher for those who produce durable output and lower for those who produce perishables or spot products (i.e., utility sales to residential customers, hotel services, and entertainment). Even some durable manufacturing enterprises would seem to have severe recapture limits because they already work three shifts per day. However, work on weekends, excess capacity, and temporary production facilities all can be used to make up lost revenue.

Table 6-16 Proprietor's Income (2021)

Label	Occupancy Class	Income (2021) / ft² / year[1]	Income (2021) / ft² / day[1]	Wages (2021) / ft² / day[1]	Employees / ft²[2]	Output (2021) / ft² / day[1]
RES1	Single-family Dwelling	0.000	0.000	0.000	0.000	0.000
RES2	Mobile Home	0.000	0.000	0.000	0.000	0.000
RES3A	Multi-family Dwelling; Duplex	0.000	0.000	0.000	0.000	0.000
RES3B	Multi-family Dwelling; Triplex/Quad	0.000	0.000	0.000	0.000	0.000
RES3C	Multi-family Dwelling; 5–9 units	0.000	0.000	0.000	0.000	0.000
RES3D	Multi-family Dwelling; 10–19 units	0.000	0.000	0.000	0.000	0.000
RES3E	Multi-family Dwelling; 20–49 units	0.000	0.000	0.000	0.000	0.000
RES3F	Multi-family Dwelling; 50+ units	0.000	0.000	0.000	0.000	0.000
RES4	Temporary Lodging	48.303	0.132	0.311	0.003	0.693
RES5	Institutional Dormitory	0.000	0.000	0.000	0.000	0.000
RES6	Nursing Home	80.505	0.221	0.519	0.005	1.156
COM1	Retail Trade	29.805	0.082	0.285	0.004	0.603

Label	Occupancy Class	Income (2021) / ft² / year[1]	Income (2021) / ft² / day[1]	Wages (2021) / ft² / day[1]	Employees / ft²[2]	Output (2021) / ft² / day[1]
COM2	Wholesale Trade	48.881	0.134	0.351	0.002	0.784
COM3	Personal and Repair Services	64.404	0.176	0.415	0.004	0.925
COM4	Professional/ Technical/ Business Services	507.476	1.390	0.494	0.004	1.351
COM5	Banks	579.090	1.587	0.805	0.006	4.387
COM6	Hospital	80.505	0.221	0.519	0.005	1.156
COM7	Medical Office/Clinic	161.009	0.441	1.039	0.010	2.311
COM8	Entertainment & Recreation	295.273	0.809	0.644	0.007	1.457
COM9	Theaters	96.605	0.265	0.624	0.006	1.388
COM10	Parking	0.000	0.000	0.000	0.000	0.000
IND1	Heavy	122.166	0.335	0.554	0.003	2.342
IND2	Light	122.166	0.335	0.554	0.003	2.342
IND3	Food/Drugs/ Chemicals	162.887	0.446	0.741	0.004	3.123
IND4	Metals/Minerals Processing	370.102	1.014	0.572	0.003	2.478
IND5	High Technology	244.332	0.669	1.110	0.006	4.683
IND6	Construction	119.103	0.326	0.600	0.005	2.321
AGR1	Agriculture	113.026	0.310	0.123	0.004	1.156
REL1	Church/ Membership Organization	64.404	0.176	0.415	0.004	2.311
GOV1	General Services	52.893	0.145	3.986	0.025	0.925
GOV2	Emergency Response	0.000	0.000	6.060	0.038	1.062
EDU1	Schools/ Libraries	80.505	0.221	0.519	0.005	4.478
EDU2	Colleges/ Universities	161.009	0.441	1.039	0.010	6.806

[1]Values adjusted using CPI to 2021 from original values from the development of Hazus by NIBS in 1999.

[2]Values from NSI 2022.

Table 6-17 provides the full set of recapture factors (wage, income, and output recapture factors) that are used with the hazard-specific equations to estimate the various types of income losses for the economic sectors used in the direct economic loss module for all hazards.

Table 6-17 Hazus Recapture Factors[1]

Specific Occupancy	Wage Recapture (%)	Employment Recapture (%)	Income Recapture (%)	Output Recapture (%)
RES1	0	0	0	0
RES2	0	0	0	0
RES3	0	0	0	0
RES4	0.60	0.60	0.60	0.60
RES5	0.60	0.60	0.60	0.60
RES6	0.60	0.60	0.60	0.60
COM1	0.87	0.87	0.87	0.87
COM2	0.87	0.87	0.87	0.87
COM3	0.51	0.51	0.51	0.51
COM4	0.90	0.90	0.90	0.90
COM5	0.90	0.90	0.90	0.90
COM6	0.60	0.60	0.60	0.60
COM7	0.60	0.60	0.60	0.60
COM8	0.60	0.60	0.60	0.60
COM9	0.60	0.60	0.60	0.60
COM10	0.60	0.60	0.60	0.60
IND1	0.98	0.98	0.98	0.98
IND2	0.98	0.98	0.98	0.98
IND3	0.98	0.98	0.98	0.98
IND4	0.98	0.98	0.98	0.98
IND5	0.98	0.98	0.98	0.98
IND6	0.95	0.95	0.95	0.95
AGR1	0.75	0.75	0.75	0.75
REL1	0.60	0.60	0.60	0.60
GOV1	0.80	0.80	0.80	0.80
GOV2	0	0	0	0
EDU1	0.60	0.60	0.60	0.60
EDU2	0.60	0.60	0.60	0.60

[1]Values from the original development of Hazus by NIBS in 1999.

Section 7. Essential Facilities: Medical Care, Emergency Response, and Schools

Essential facilities (EF) are those facilities that provide services to the community and should be functional after an event. Essential facilities include medical care facilities, fire stations, police stations, EOCs, and schools. Damage to essential facilities is determined on a site-specific basis. The purpose of the essential facility modules for each hazard (currently only Earthquake, Flood, and Hurricane) is to determine the expected loss of functionality for these critical facilities. The data required for the analysis includes mapping of the essential facility occupancy class to a specific building type, or a combination of essential facility building type and design level.

Table 7-1 summarizes the spatial database elements for medical, emergency response, and schools by data type, sources and geographic coverage. Table 7-2 provides the tabular database elements for medical, emergency response, and schools by data type, hazard, and sources.

Table 7-1 Baseline Essential Facilities Spatial Database Elements for Medical Care, Emergency Response, and Schools

EF Data Type	Data Element	Hazus 6.0 Dataset Date	Hazus 6.0 Dataset Source	Geographic Coverage
Medical Care Spatial Data	Hospital Geometries (Lat/Long)	June 2022	HIFLD Open: Hospitals. Hospital records with STATUS = “Closed” have been omitted.	All U.S.
Medical Care Spatial Data	Hospital Geometries (Lat/Long)	Oct. 2022	HIFLD Open: Veteran’s Health Administration Medical Facilities (VHAMF). Records in the VHAMF layer co-located with records determined to be duplicates in the Hospitals layer have been omitted.	All U.S.
Emergency Response: Fire Station Spatial Data	Fire Geometries (Lat/Long)	Sept. 2020	HIFLD Open: Fire Stations	CONUS, AK, PR
Emergency Response: Fire Station Spatial Data	Fire Geometries (Lat/Long)	2018	State of Hawaii (2018)	HI
Emergency Response: Fire Station Spatial Data	Fire Geometries (Lat/Long)	2019	City and County of Honolulu	HI
Emergency Response: Fire Station Spatial Data	Fire Geometries (Lat/Long)	2017[1]	Global Hazards Information Network (GHIN) for U.S. Territories of AS, GU, and MP	AS, GU and MP

EF Data Type	Data Element	Hazus 6.0 Dataset Date	Hazus 6.0 Dataset Source	Geographic Coverage
Emergency Response: Fire Station Spatial Data	Fire Geometries (Lat/Long)	2019[2]	Best available local data for VI	VI
Emergency Response: Police Station Spatial Data	Police Geometries (Lat/Long)	Feb. 2021	HIFLD Open: Local Law Enforcement Locations	CONUS, AK, PR
Emergency Response: Police Station Spatial Data	Police Geometries (Lat/Long)	2018	State of Hawaii	HI
Emergency Response: Police Station Spatial Data	Police Geometries (Lat/Long)	2019	City and County of Honolulu	HI
Emergency Response: Police Station Spatial Data	Police Geometries (Lat/Long)	2017[1]	GHIN for U.S. Territories of AS, GU, and MP	AS, GU and MP
Emergency Response: Police Station Spatial Data	Police Geometries (Lat/Long)	2019[2]	Best available local data for VI	VI
Emergency Response: EOC Spatial Data	EOC Geometries (Lat/Long)	Apr. 2018	HIFLD Open: Local EOC. Local EOCs identified as mobile units (NAME includes “mobile”) have been omitted (except for the Mobile County EOC in AL).	All U.S.
Emergency Response: EOC Spatial Data	EOC Geometries (Lat/Long)	Jan. 2022	HIFLD Open: State EOC	All U.S.
Emergency Response: EOC Spatial Data	EOC Geometries (Lat/Long)	Jan. 2022	HIFLD Open: FEMA Regional Offices	All U.S.
Emergency Response: EOC Spatial Data	EOC Geometries (Lat/Long)	2018	State of Hawaii	HI
Emergency Response: EOC Spatial Data	EOC Geometries (Lat/Long)	2019	City and County of Honolulu	HI

EF Data Type	Data Element	Hazus 6.0 Dataset Date	Hazus 6.0 Dataset Source	Geographic Coverage
Schools Spatial Data	School Geometries (Lat/Long)	May 2022	HIFLD Open: Public Schools Public Schools with Status = 2 (Closed), 6 (Inactive), or 7 (Future School) have been omitted. Schools other than in-person (NAME includes “online”, “on-line”, “virtual”, “cyber” and “distance”) have been omitted.	All U.S.
Schools Spatial Data	School Geometries (Lat/Long)	May 2022	HIFLD Open: Private Schools. Schools other than in-person (NAME includes “online”, “on-line”, “virtual”, “cyber” and “distance”) have been omitted.	All U.S.
Schools Spatial Data	School Geometries (Lat/Long)	March 2022	HIFLD Open: Colleges and Universities. Colleges & Universities with Status = “C” (Combined), “D” (Delete), “G” (Child campus) and “M” (Closed) have been omitted. Schools other than in-person (NAME includes “online”, “on-line”, “virtual”, “cyber” and “distance”) have been omitted. For the Colleges and Universities database, additional filters were applied to identify and remove several very large distance learning institutions, e.g., 'UNIVERSITY OF PHOENIX-ARIZONA’.	All U.S.
Schools Spatial Data	School Geometries (Lat/Long)	May 2022	HIFLD Open: Supplemental Colleges. Supplemental Colleges with Status = “C” (Combined), “D” (Delete), “G” (Child campus) and “M” (Closed) have been omitted. Schools other than in-person (NAME includes “online”, “on-line”, “virtual”, “cyber” and “distance”) have been omitted.	All U.S.
Schools Spatial Data	School Geometries (Lat/Long)	2018	State of Hawaii	HI
Schools Spatial Data	School Geometries (Lat/Long)	2019	City and County of Honolulu (2019)	HI
Schools Spatial Data	School Geometries (Lat/Long)	2017[1]	GHIN for U.S. Territory of MP	MP

EF Data Type	Data Element	Hazus 6.0 Dataset Date	Hazus 6.0 Dataset Source	Geographic Coverage
Schools Spatial Data	School Geometries (Lat/Long)	2019[2]	Best available local data for VI	VI

[1]U.S. Territory Essential Facilities (except Puerto Rico and U.S. Virgin Islands) were completed in 2017 and developed by the Pacific Disaster Center using public sources. The sources for these data varied depending on the territory, and the metadata for the layers can be found at the [Global Hazards Information Network (GHIN) website](#).

[2]U.S. Virgin Islands data were added to Hazus databases in 2019 (FEMA, 2019).

[3]For more information, see Section 6.6 of the Hazus Earthquake Model User Guidance.

Table 7-2 Baseline Essential Facilities Tabular Database Elements for Medical Care, Emergency Response, and Schools

EF Data Type	Data Element	Hazards	Hazus 6.0 Dataset Source
EF Class Tabular Data	EF Usage Classification	All	Attributes established for each EF Class (see Table 7-3).
EQ and TS Bldg. Type for EF Class Tabular Data	Mapping Scheme: EQ Bldg. Type	EQ, TS	Regional or State Assumption aligned with benchmark year code dates, urban or rural designation and estimated year built. The state-by-state assignments are stored within the CDMS SQL database in the eqEFBldgType table.
FL Bldg. Type for EF Class Tabular Data	Mapping Scheme: FL Bldg. Type	FL	Assumed from EF Usage Class.
HU Bldg. Type for EF Class Tabular Data	Mapping Scheme: HU Bldg. Type	HU	Region, State or Sub-State Assumption.
EF Structure Replacement Value	Structure Value	All	2022 Replacement Value Model (see Section 7.2).
Foundation Type Tabular Data	Foundation Type	EQ, FL	Community Level (FL) or National (EQ) Assumption.
Design Level Tabular Data	Design Level	EQ	Regional Assumption aligned with benchmark year code dates, urban or rural designation and estimated year built.
Landslide Susceptibility Tabular Data	Landslide Susceptibility	EQ	National Default (0).[1]
Liquefaction Susceptibility Tabular Data	Liquefaction Susceptibility	EQ	National Default (0). [1]
Soil Type Tabular Data	Soil Type	EQ	National Default (D); USGS with site-soil amplification for Probabilistic and ShakeMaps.
Wind Building Characteristics Tabular Data	Wind Building Characteristics	HU	Region, State or Sub-State Assumption.

[1]For more information, see Section 6.6 of the Hazus Earthquake Model User Guidance.

7.1 Classification

Essential facilities are classified based on facility function and, in the case of hospitals, size. Table 7-3 lists the classes of essential facilities used in the Hazus Methodology. Hospitals are classified according to number of beds, since the structural and nonstructural systems of a hospital are related to the size of the hospital (i.e., to the number of beds it contains).

Table 7-3 Classification of Essential Facilities

Label	Occupancy Class	Description
Medical Care Facilities		
MDFLT	Default Hospital	Assigned features similar to EFHM
EFHS	Small Hospital	Hospital with fewer than 50 Beds
EFHM	Medium Hospital	Hospital with beds between 50 & 150
EFHL	Large Hospital	Hospital with more than 150 Beds
EFMC	Medical Clinics	Clinics, Labs, Blood Banks
Emergency Response		
FDFLT	Default Fire Station	-
EFFS	Fire Station	-
PDFLT	Default Police Station	-
EFPS	Police Station	-
EDFLT	Default EOC	-
EFEO	Emergency Operation Centers	-
Schools		
SDFLT	Default School	Assigned features similar to ESF1
EFS1	Schools	Primary/Secondary Schools (K-12)
EFS2	Colleges/Universities	Community and State Colleges, State and Private Universities

7.2 Replacement Cost Models

Replacement cost models for each type of essential facility developed are described below.

7.2.1 Medical Care

For the hospital replacement cost model, a generalized construction rule-of-thumb is used to estimate building square footage. Based on recent hospital construction projects and industry commentary, a value of 2,500 square feet per bed is utilized[4].

The majority of records in the HIFLD Open Hospitals data set include data on the number of beds, allowing for facility classification into Hazus classes of Small, Medium and Large Hospitals (see Table

[4] See, for example, https://healthcaredesignmagazine.com/trends/research-theory/8-considerations-benchmarking/

7-3), as well as estimation of building-specific square footage. Using the available bed data in the 2021 HIFLD Open Hospitals data set examined during replacement cost model development, the 2,500 square foot per bed rule-of-thumb was used to select a representative building size for each Hazus hospital class; 70,000, 225,000 and 300,000 square feet for Small, Medium and Large Hospitals, respectively. These building sizes were then used to derive an average cost per square foot from selected replacement cost models applicable to each category, provided in Table 7-4. Replacement values are estimated from bed count (where available), the square footage rule-of-thumb, and the replacement model cost per square foot. When bed count data are not available, facilities in the HIFLD Open Hospitals database are assumed to be Medium Hospitals. Replacement costs are localized by the application of county-level non-residential construction cost multipliers utilized for the GBS (see Section 6).

The HIFLD Open VHAMF data set does not include hospital bed data, so replacement cost models are selected based on the facility's NAICS category, as delineated in Table 7-4. Veterans Health Administration Hospitals are modeled as Medium Hospitals. Outpatient Clinics are modeled as medical offices, with a replacement cost model that is similar to but slightly larger than the model applied to COM7 facilities in the General Building Stock (see Table 6-2), based on available building size data specific to Veterans Health Administration outpatient clinics. Finally, the Nursing Home replacement cost model applied here is the same as the model applied to RES6 construction in the GBS (see Table 6-2).

Table 7-4 Replacement Cost Models for Medical Care Facilities

Model Description	Assumed Building Size (ft^2), When Required	Replacement Cost/ft^2 (2022)	Application Criteria: HIFLD Hospitals – "BEDS" Value	Application Criteria: HIFLD VHAMF - NAICS Code Description
Small Hospital	N/A	$389.23	BEDS < 50	N/A
Medium Hospital	225,000 (for records without bed data only)	$327.63	50 ≥ BEDS ≤ 150, and records with no beds data available	"GENERAL MEDICAL AND SURGICAL HOSPITALS", and "SPECIALTY (EXCEPT PSYCHIATRIC AND SUBSTANCE ABUSE) HOSPITALS"
Large Hospital	N/A	$325.27	BEDS > 150	N/A
Medical Office	11,500	$260.93	N/A	"OTHER OUTPATIENT CARE CENTERS"[1]
Nursing Home (same as RES6)	25,000	$261.45	N/A	"NURSING HOMES (SKILLED NURSING FACILITIES)"

[1]Also applied to records identified as "OTHER OUTPATIENTRANCE CARE CENTERS" (typo in HIFLD Open data).

7.2.2 Fire Stations

For the fire station replacement cost model, typical fire station building sizes have been assumed for volunteer and traditional fire departments in urban and non-urban areas based on available data, including fire station configuration information assembled for three FEMA-sponsored county-wide Hazus risk assessment studies in southern California (MapIX-Mainland et al., 2009a, 2009b, 2009c) and the results of a limited web search which identified 40 recent construction projects nationwide. Available data indicate that stations in urban areas are generally larger than their counterparts in non-urban areas. In addition, in the 2021 HIFLD Open Fire Station data examined during replacement cost model development, 30% of records represented volunteer fire departments, which are most common in the eastern and southern states. Fire stations for volunteer departments may not have sleeping quarters (FEMA, 1997), so these stations have been modeled as smaller facilities.

Four replacement cost models, reflecting the expected difference in size for urban and non-urban stations, and for Volunteer Fire Departments and traditional Fire Departments, have been derived as an average cost per square foot for the assumed building sizes for selected replacement cost models, as shown in Table 7-5. Replacement costs are localized by the application of county-level non-residential construction cost multipliers utilized for the GBS (see Section 6.3).

Fire station location relative to urban areas has been determined based on the 2021 Census Urban Area National GIS data. The Urban Area data categorize areas as follows:

- Urbanized Areas (field “UATYPE10” = “U”) contain 50,000 or more people
- Urban Clusters (field “UATYPE10” = “C”) contain at least 2,500 people, but fewer than 50,000 people

Facilities falling outside the Urbanized Areas and Urban Clusters are considered rural. Based on available data, fire stations in Urban Cluster areas followed development trends most similar to rural areas, so these areas have been grouped together and are considered “Non-Urban” areas. The resulting urban area classifications are stored in HIFLD-derived SQL tables (e.g., SQL table hifld_FireStation), where applicable. Data are stored in the field “UATYP,” where “U” is urban and “R” is rural or non-urban, and includes both the Urban Cluster areas as well as the rural areas.

Table 7-5 Replacement Cost Models for Fire Stations

Model Description	Assumed Building Size (ft^2)	Replacement Cost/ft^2 (2022)	Application Criteria: HIFLD Fire Stations
Non-Urban Fire Station for Volunteer Fire Department	4,000	$229.74	Volunteer[1] Fire Departments in non-Urban Areas
Non-Urban Fire Station for Traditional Fire Department	5,500	$216.16	All Other Fire Departments in non-Urban Areas
Urban Fire Station for Volunteer Fire Department	6,000	$211.94	Volunteer[1] Fire Departments in Urban Areas
Urban Fire Station for Traditional Fire Department	8,000	$203.84	All Other Fire Departments in Urban Areas

[1]Volunteer fire departments have been identified as facilities whose name contains “VFD,” “Vol.,” or “Volun.”

7.2.3 Police Stations

Replacement cost models have been developed to reflect the variety of facility types included in the HIFLD Open Law Enforcement Locations database: police stations, state prisons, and local/county jails. Similar to the fire station replacement cost model development, typical police station and jail/prison building sizes have been assumed based on available data, information assembled for three county-wide Hazus risk assessment studies in southern California (MapIX-Mainland et al., 2009a, 2009b, 2009c) and the results of a limited web search. The web search identified 37 recent police station construction projects nationwide. Available data indicate that, like fire stations, police stations in urban areas are generally larger than their counterparts in non-urban areas. In addition, recent construction project data for 37 jail/prison facilities (30 county/local facilities and 7 state prisons) were reviewed. As most state prisons are expected to be located in non-urban areas and county/local facilities will be located within urban areas, differentiation of the jail and prison replacement cost model by urban/non-urban was not required.

Replacement cost models for the various law enforcement facility types have been derived as an average cost per square foot for the assumed building sizes for selected replacement cost models, as shown in Table 7-6. Replacement costs are localized by the application of the same county-level non-residential construction cost multipliers utilized for the GBS. It should be noted that the non-urban police station model is the same as the GOV2 model applied to the GBS (see Table 6-2).

Table 7-6 Replacement Cost Models for Police Stations and Other Law Enforcement Facilities

Model Description	Assumed Building Size (ft^2)	Replacement Cost/ft^2 (2022)	Application Criteria: HIFLD Local Law Enforcement Facilities
Non-Urban Police Station (same as GOV2)	11,000	$284.46	Police Stations (all non-Jail/Prison facilities) in non-Urban Areas
Urban Police Station	36,000	$237.06	Police Stations (all non-Jail/Prison facilities) in Urban Areas
State Prison	145,000	$330.09	Jail/Prison[1] Facilities with Facility Type "Primary State Agency"
County/Local Jail	100,000	$336.04	Jail/Prison[1] Facilities, all other Facility Types

[1]Jail/Prison facilities have been identified as facilities whose name contains "Jail," "Prison," "Correction," or "Detention."

7.2.4 Emergency Operations Centers

Replacement cost models have been developed to reflect the variety of facility types included in the three HIFLD Open Emergency Operations Center databases; local EOCs, State EOCs, and FEMA Regional offices. Similar to the fire station and police station replacement cost model development, typical state and local EOC building sizes have been assumed based on available data; information assembled for three county-wide Hazus risk assessment studies in southern California (MapIX-Mainland et al., 2009a, 2009b, 2009c) and the results of a limited web search that identified 33 recent EOC construction projects nationwide, including 26 city/county EOCs and 7 state EOCs.

EOCs are often co-located with other facilities, such as police stations or fire stations. Of the 72% of local EOC facilities in the 2021 HIFLD Open database where co-location could be readily identified, most (42%) were co-located with police and courthouse facilities, 16% with fire facilities, and 14% with other city municipal buildings. Similar percentages were observed in the recent construction project data collected. Given the frequency with which local EOCs are located with police facilities, the replacement cost models for local EOCs are derived from the police station models described above. In addition, the available data indicate that, like fire and police stations, local EOCs in urban areas are generally larger than their counterparts in non-urban areas.

Based on available data on state EOCs, these typically larger facilities are assumed to be multi-use, reasonably represented by an office replacement cost model. Similarly, office replacement cost models of varying size have been selected to represent the various FEMA Regional Office types.

Replacement cost models have been derived as an average cost per square foot for the assumed building sizes for selected replacement costs models, as shown in Table 7-7. Replacement costs are localized by the application of same county-level non-residential construction cost multipliers utilized for the General Building Stock. It should be noted that the non-urban local EOC model is the same as the non-urban police station model and the GOV2 model applied to the General Building Stock (see Table 6-2).

Table 7-7 Replacement Cost Models for Emergency Operations Centers

Model Description	Assumed Building Size (ft²)	Structure Replacement Cost/ft² (2022)	Application Criteria: HIFLD Local and State EOCs and FEMA Regional Offices
Non-Urban Local EOC (same as GOV2)	11,000	$284.46	Non-Urban Local EOCs
Urban Local EOC	30,000	$242.56	Urban Local EOCs
State EOC	50,000	$185.69	State EOCs
FEMA Area Office	7,000	$215.88	FEMA Regional Offices, Type = “area”
FEMA Regional Office	20,000	$205.88	FEMA Regional Offices, Type = “regional”
FEMA National Office	80,000	$204.43	FEMA Regional Offices, Type = “national”

7.2.5 Schools

7.2.5.1 PUBLIC SCHOOLS

To support the development of public school replacement cost models, relationships between square footage and students at schools of varying levels were sought. The most relevant data found were a series of annual surveys, published by “School Planning & Management” (SPM) Magazine, tabulating data on school construction projects (SPM, 2007). These data included annual national median square feet per student for elementary, middle and high schools, along with counts of construction projects represented. For the eight available surveys (conducted between 2008 and 2015), a total of 5,052 construction projects are represented; this number represents approximately 5% of the more than 100,000 records in the 2021 version of the HIFLD Open Public Schools Database.

In addition to the construction surveys, available data on school type, size and enrollment have been collected and reviewed, examining the resultant square feet per student, including:

- Extensive building level school data derived from insurance appraisal reports assembled for the three FEMA-sponsored Hazus essential facilities risk assessment studies conducted in southern California in 2009 (MapIX-Mainland, 2009a, 2009b and 2009c), reflecting more than 25,000 public school buildings in Orange, Riverside and San Bernardino Counties.

- School construction project data assembled by the California Department of Education (CDE) for 60 school projects (27 elementary schools, 15 middle schools, and 18 high schools) in 2007 (CDE, 2007).

In addition to national median square feet per student, the SPM annual construction reports provide additional data by region. For most regions, the variation from the national median is modest, except for the Western region (Zone 11 including Arizona, California, Hawaii and Nevada); the reports note that climate in the West makes it possible to build schools without corridors, so square feet per student is generally lower than the national median. This conclusion is supported by the CDE data.

Further, the available survey data indicates that although there is significant year to year variation, all three school levels demonstrate a pattern of increasing square feet per student over time. It should be noted, however, that the HIFLD Open schools databases (and the resulting Hazus schools database) represent a wide range of construction vintages, which would not necessarily be well represented by applying models based on the most recent construction patterns. For example, in the 2009 schools data available for the three Southern California Counties, the average year built for all school buildings was 1987.

To best reflect the varying construction vintages present in the HIFLD Open Public Schools data, the available data (SPM survey data, California CDE construction project information, three county schools data) were combined to derive representative square footage allocations per student for Elementary, Middle and High Schools, provided in Table 7-8. Allocations are also provided for Adult Education facilities (assumed to have space requirements similar to high school facilities), Secondary schools (combined Middle and High schools, with their space allocation averaged accordingly), and Ungraded schools (with space allocations averaged for Elementary, Middle and High schools).

As with other essential facilities, it was observed that schools in urban areas were generally larger than their counterparts in non-urban areas. Average 2021 HIFLD Open Public Schools enrollments for urban and non-urban areas, for both the Western Region and the rest of the U.S., have been estimated for the various school levels, and are also provided in Table 7-8.

Table 7-8 Square Foot Allocations and Average Enrollments from the 2021 HIFLD Open Public Schools Database

HIFLD Open Public Schools, Field: "LEVEL_"	Square Feet per Student: Western[1] Region	Square Feet per Student: Other Regions	Average Enrollment (Number of Students): Western Region, Urban Areas[4]	Average Enrollment (Number of Students): Western Region, Non-Urban Areas[4]	Average Enrollment (Number of Students): Other Regions, Urban Areas[4]	Average Enrollment (Number of Students): Other Regions, Non-Urban Areas[4]
ELEMENTARY	71	96	554	348	502	366
MIDDLE	98	124	791	451	693	413
HIGH	129	155	1003	423	933	444
OTHER[2]	99	125	494	346	480	279
UNGRADED[2]	99	125	63	17	87	34
NOT APPLICABLE[2] and NOT REPORTED[2]	99	125	415	205	415	205
SECONDARY[3]	114	140	53	36	301	240
ADULT EDUCATION	129	155	553	553	553	553
PREKINDERGARTEN	35	35	68	75	202	102

[1]Western Region includes AZ, CA, HI, and NV.

[2]Square feet per student calculated as an average of Elementary, Middle and High school.

[3]Square feet per student calculated as an average of Middle and High school.

[4]Average enrollment values are applied when enrollment data are not available in the HIFLD Open database.

These average enrollment values are applied when enrollment data are not available in the HIFLD Open database. In addition, the square footage allocations and average enrollments have been used to estimate typical urban and non-urban facility sizes, for which average costs per square foot have been derived for selected replacement cost models provided in Table 7-9.

As noted above, adult education facilities that are part of public school districts are assumed to have similar space requirements as high school facilities, so the square foot per student for high schools has been assumed. Adult education facility data are too sparse to differentiate typical enrollment by region or urban area, so the overall average enrollment is universally applied.

Finally, childcare/day care facilities (i.e., prekindergarten facilities) are generally state regulated, with a minimum of 35 square feet per child (examples include California, Arkansas, Arizona and Florida). No distinction has been made between urban and non-urban facilities.

It should be noted that prior to replacement cost estimation, the Public Schools database was filtered as described in Table 7-3. That is, school records with "Status" other than "Operational," "New," "Added," and "Changed Agency," and schools identified as virtual are omitted from the database such that default enrollments are only applied to operating and in-person schools.

Table 7-9 Replacement Cost Models for Public Schools

Model Description	Structure Replacement Cost/ft² (2022)	Application Criteria: HIFLD Public Schools – "Level"
Non-Urban Elementary School	$212.57	"ELEMENTARY"
Urban Elementary School	$209.53	"ELEMENTARY"
Non-Urban Middle School	$216.80	"MIDDLE"
Urban Middle School	$212.49	"MIDDLE"
Non-Urban High School	$244.97	"HIGH"
Urban High School	$237.73	"HIGH"
Other Non-Urban Public School	$224.78	"OTHER," "UNGRADED," "NOT APPLICABLE," "NOT REPORTED"
Other Urban Public School	$219.92	"OTHER," "UNGRADED," "NOT APPLICABLE," "NOT REPORTED"
Non-Urban Secondary School	$230.89	"SECONDARY"
Urban Secondary School	$225.11	"SECONDARY"
Adult Education School	$196.17	"ADULT EDUCATION"
Pre-Kindergarten	$247.00	"PREKINDERGARTEN"

7.2.5.2 PRIVATE SCHOOLS

Private school types in the HIFLD Open database are limited to elementary, secondary and combined (all grades, equivalent to the public school category of "UNGRADED"). Private schools are assumed to have fewer students per classroom than public schools, so the larger, non-Western public school square feet per student allocations have been assumed for the equivalent private schools, as provided in Table 7-10.

Similar to the Public Schools, it was observed that HIFLD Open Private Schools in urban areas were generally larger than their counterparts in non-urban areas. Further, a larger proportion of the Private Schools are located in urban areas (72% vs. 59% for Public Schools). Typical facility sizes for urban and non-urban areas were estimated from the 2021 HIFLD Open Private Schools data, and average costs per square foot were derived for the assumed building sizes for selected replacement cost models. These replacement cost models are provided in Table 7-11. Finally, all schools in the HIFLD Open Private Schools database have, by definition, non-zero enrollment data (i.e., are operational), so average enrollments by level are not required for replacement cost model implementation. Similar to Public Schools, only in-person schools are included in the database, as described in Table 7-3.

Table 7-10 Private School Square Foot Allocations

HIFLD Private Schools, Field: "LEVEL_" (Description)	Square Feet per Student (ft²/Student) - All Regions
1 (Elementary (K-6))	96
2 (Secondary (7–12))	140
3 (Combined)	125

Table 7-11 Replacement Cost Models for Private Schools

Model Description	Structure Replacement Cost/ft² (2022)	Application Criteria: HIFLD Private Schools – “Level”
Non-Urban Private Elementary School	$238.49	1
Urban Private Elementary School	$214.50	1
Non-Urban Private Secondary/ Combined School	$210.92	2, 3
Urban Private Secondary School	$199.57	2
Urban Private Combined School	$204.42	3

7.2.5.3 COLLEGES & UNIVERSITIES AND SUPPLEMENTAL COLLEGES

To support the development of the college and university replacement cost models reflected in the Hazus College & University (EDU2) database, available data on college and university size and enrollment were collected and reviewed, examining the resultant square feet per student. Data for gross building square footage and enrollment was assembled for 52 individual College/University campuses from space inventory and other data nationwide and included comprehensive data from individual campus space management reports for each of the 23 schools in the California State University System, as well as square footage and enrollment by community college district for all 72 community college districts in California (CCCCO, 2016). The resulting average square feet per student for the assembled data by campus type are provided in Table 7-12.

As expected, the average square feet per student at junior colleges is smaller than that for colleges and universities, as the junior college campuses are less likely to include student housing. The average college and university square feet per student is significantly larger than the largest allocation for primary and secondary schools discussed above (see Table 7-8).

Though the junior college square feet per student allocation outside the Western Region is slightly larger than the high school allocation inside the Western Region, the estimated 64 square feet per student is well below the high school allocation. Nevertheless, because the data collected for California are a complete representation of the Community College District (CCD) facilities in that state, the allocation is believed to be reliable.

Since the HIFLD Open records identified as “Colleges, Universities, and Professional Schools” and “Junior Colleges” in both the Colleges & Universities and Supplemental College databases are mainly located in urban areas (74% of facilities are located in urban areas) no distinction is made between urban and non-urban facilities.

In addition, because colleges are expected to be multi-building campuses, one other metric has been taken from the assembled data; for the 61 campuses where building counts are available (5,568 building total), the average square footage per building has been estimated to be about 45,000 square feet. This data was used to inform the selection of the building size for the derivation of average cost per square foot for the selected replacement cost model, as provided in Table 7-14. The same replacement cost model is applied to both “Colleges, Universities, and Professional Schools” and

"Junior Colleges." Note that this is also the current default EDU2 replacement cost model (see Table 6-2).

Enrollment for facilities in the HIFLD Open Colleges & Universities database lacking enrollment data has been estimated from average enrollments of facilities by size category, rather than using overall averages, i.e., using enrollment averages for field INST_SIZE, where class 1 is defined as "<1,000 students," and class 2 is defined as "1,000 to 4,999 students." It should be noted that prior to replacement cost estimation, both the Colleges & Universities and Supplemental College databases are filtered as described in Table 7-3. That is, records with "Status" other than "Active," "New," and "Restored," and schools identified as virtual are omitted from the database such that default enrollments are only applied to operating and in-person schools.

The HIFLD Open Supplemental Colleges database does not include data on institution size. Based on a comparison of available Supplemental College facility enrollment for "Colleges, Universities, and Professional Schools" and "Junior Colleges" to equivalent College & University enrollment by size category, the most appropriate average to apply when Supplemental College records lack enrollment data was determined to be an average of College & University Class 1 and 2 facilities.

For the remaining seven facility types (see Table 7-12, Table 7-13 and Table 7-14), the following assumptions have been made:

- These facilities are principally located in urban areas (85% are located in urban areas), so no distinction is made between urban and non-urban facilities.
- For flight training schools, facilities are assumed to be hangar facilities with built-in classrooms. Further, it is assumed that enrollment is not a good measure of facility size for flight training schools, as due to limitations on the number of aircraft, it is assumed that not all students will be in attendance at once. A typical building size of 20,000 square feet has been assumed.
- Educational support services facilities are college system or district offices and are assumed to be typical office facilities. A mid-size office of 50,000 square feet has been selected.
- For the other facility types (HIFLD Open field NAICS_DESC = "Business and Secretarial Schools," "Computer Training," "Cosmetology and Barber Schools," "Fine Arts Schools" and "Other Technical And Trade Schools"), the square footage allocation for non-Western Junior Colleges has been applied, assuming that these facilities are more likely to be housed in a single building, thereby negating the size reduction applied in the West for outdoor corridors. Representative building replacement cost models have been derived based on typical building sizes derived from average enrollment by facility type and the assumed square foot allocation.

Table 7-12 Square Foot Allocations from the 2021 HIFLD Open Colleges & Universities and Supplemental Colleges Data

HIFLD Open Colleges & Universities (C&U), Supplemental Colleges (SC), Field: "NAICS_DESC"	Square Feet per Student (ft^2/ Student): Western Region	Square Feet per Student (ft^2/ Student): Other Regions
Colleges, Universities, and Professional Schools	245	383
Junior Colleges	64	176
Cosmetology and Barber Schools	176	176
Business and Secretarial Schools	176	176
Other Technical and Trade Schools	176	176
Fine Arts Schools	176	176
Computer Training	176	176
Flight Training	N/A	N/A
Educational Support Services	N/A	N/A

Table 7-13 Average Enrollments from the 2021 HIFLD Open Colleges & Universities and Supplemental Colleges Data[1]

HIFLD Open Colleges & Universities (C&U), Supplemental Colleges (SC), Field: "NAICS_DESC"	Avg. Enroll., C&U "Inst_Size" = 1, Applied to C&U	Avg. Enroll., C&U "Inst_Size" = 2, Applied to C&U	Avg. Enroll., C&U "Inst_Size" = 1 & 2 Combined, Applied to SC	Avg. Enroll., C&U "Inst_Size" = 1, Applied to SC	Assumed Sq. Ft., where applicable
Colleges, Universities, and Professional Schools	362	N/A	1,352	N/A	N/A
Junior Colleges	363	2,651	1,458	N/A	N/A
Cosmetology and Barber Schools	110	N/A	N/A	110	N/A
Business and Secretarial Schools	226	N/A	N/A	226	N/A
Other Technical and Trade Schools	188	N/A	N/A	188	N/A
Fine Arts Schools	164	N/A	N/A	164	N/A
Computer Training	347	N/A	N/A	347	N/A
Flight Training	N/A	N/A	N/A	N/A	20,000
Educational Support Services	N/A	N/A	N/A	N/A	50,000

[1]*Average Enrollment (Number of Students) or Assumed Square Footage.*

Table 7-14 Replacement Cost Models for Colleges & Universities and Supplemental Colleges

Model Description	Structure Replacement Cost/ft² (2022)	Application Criteria: HIFLD Colleges & Universities and Supplemental Colleges– "NAICS_DESC"
College classroom (same as EDU2)	$197.10	"COLLEGES, UNIVERSITIES, AND PROFESSIONAL SCHOOLS," "JUNIOR COLLEGES"
Cosmetology school	$210.92	"COSMETOLOGY AND BARBER SCHOOLS"
Trade school	$201.15	"BUSINESS AND SECRETARIAL SCHOOLS," "OTHER TECHNICAL AND TRADE SCHOOLS"
Fine Arts school	$199.57	"FINE ARTS SCHOOLS"
Computer Training	$195.69	"COMPUTER TRAINING"
Flight Training	$172.19	"FLIGHT TRAINING"
Educational Support Services	$185.69	"EDUCATIONAL SUPPORT SERVICES"

7.3 Spatial and Tabular Data

Essential facility spatial data and certain tabular data are directly updated from the Homeland Infrastructure Foundation-Level Data (HIFLD) Open datasets. Table 7-1 and Table 7-2 summarized the specific HIFLD Open databases used to populate the Hazus EF data. The following sections provide some additional information on using HIFLD Open data.

7.3.1 Medical Care

The following attributes are required:

- Medical Care Facility Class (All Models)
- Number of Licensed Hospital Beds (All Models)
- Building Type (All Models)
- Replacement Cost (All Models)
- Backup Power (All Models)
- WBC Mapping Scheme Name (Hurricane Model)
- Landslide Susceptibility (Earthquake Model)
- Liquefaction Susceptibility (Earthquake Model)
- Soil Type (Earthquake Model)
- Water Depth (Earthquake Model)
- Earthquake Building Type (Earthquake Model)
- Design Level (Earthquake and Flood Models)
- FFHAG (Flood Model)
- Foundation Type (Flood Model)
- Flood Protection (Flood Model)
- Number of Stories (Flood Model)

7.3.2 Fire Stations

The following attributes are required:

- Fire Station Class (All Models)
- Number of Fire Engines (Earthquake Model)
- Building Type (All Models)
- Replacement Cost (All Models)
- Backup Power (All Models)
- WBC Mapping Scheme Name (Hurricane Model)
- Landslide Susceptibility (Earthquake Model)
- Liquefaction Susceptibility (Earthquake Model)
- Soil Type (Earthquake Model)
- Water Depth (Earthquake Model)
- Earthquake Building Type (Earthquake Model)
- Design Level (Earthquake and Flood Models)
- FFHAG (Flood Model)
- Foundation Type (Flood Model)
- Flood Protection (Flood Model)
- Number of Stories (Flood Model)

7.3.3 Police Stations

The following attributes are required:

- Police Station Class (All Models)
- Building Type (All Models)
- Replacement Cost (All Models)
- Backup Power (All Models)
- WBC Mapping Scheme Name (Hurricane Model)
- Landslide Susceptibility (Earthquake Model)
- Liquefaction Susceptibility (Earthquake Model)
- Soil Type (Earthquake Model)
- Water Depth (Earthquake Model)
- Earthquake Building Type (Earthquake Model)Design Level (Earthquake and Flood Models)
- FFHAG (Flood Model)
- Foundation Type (Flood Model)
- Flood Protection (Flood Model)
- Number of Stories (Flood Model)

7.3.4 Emergency Operations Center (EOC)

The following attributes are required:

- Emergency Center Class (All Models)
- Building Type (All Models)
- Replacement Cost (All Models)
- Backup Power (All Models)
- WBC Mapping Scheme Name (Hurricane Model)
- Landslide Susceptibility (Earthquake Model)
- Liquefaction Susceptibility (Earthquake Model)
- Soil Type (Earthquake Model)
- Water Depth (Earthquake Model)
- Earthquake Building Type (Earthquake Model)
- Design Level (Earthquake and Flood Models)
- FFHAG (Flood Model)
- Foundation Type (Flood Model)
- Flood Protection (Flood Model)
- Number of Stories (Flood Model)

7.3.5 Schools

The following attributes are required:

- School Class (All Models)
- Building Type (All Models)
- Replacement Cost (All Models)
- Backup Power (All Models)
- WBC Mapping Scheme Name (Hurricane Model)
- Landslide Susceptibility (Earthquake Model)
- Liquefaction Susceptibility (Earthquake Model)
- Soil Type (Earthquake Model)
- Water Depth (Earthquake Model)
- Earthquake Building Type (Earthquake Model)
- Design Level (Earthquake and Flood Models)
- FFHAG (Flood Model)
- Foundation Type (Flood Model)
- Flood Protection (Flood Model)
- Number of Stories (Flood Model)

For data items in Table 7-1 and Table 7-2 that show regional assumptions for designating values for a state, please see Appendix A.

For the Earthquake Model, the default mapping of essential facility occupancy classes to specific building type are also provided in Appendix B.

For the Flood Model, Table 7-15 includes additional default values used for certain structure data.

Table 7-15 Essential Facilities Inventory Occupancy Classification and Flood Model Default Parameters

Hazus Label	Occupancy Class	Default Building Type	Default Foundation Type	First Floor Height (ft)	No. of Stories	Damage Functions	Functional Depth (ft)
MDFLT	Default Hospital	Concrete	Basement	3	Mid	COM6	0.5
EFHS	Small Hospital	Concrete	Basement	3	Low	COM6	0.5
EFHM	Medium Hospital	Concrete	Basement	3	Mid	COM6	0.5
EFHL	Large Hospital	Concrete	Basement	3	Mid	COM6	0.5
EFMC	Medical Center	Concrete	Basement	3	Low	COM7	0.5
FDFLT	Default Fire Station	Concrete	Slab on Grade	0	Low	GOV2	2
EFFS	Fire Station	Concrete	Slab on Grade	0	Low	GOV2	2
PDFLT	Default Police Station	Concrete	Basement	0	Low	GOV2	1
EFPS	Police Station	Concrete	Basement	0	Low	GOV2	1
EDFLT	Default Emergency Center	Concrete	Basement	0	Low	GOV2	0.5
EFEO	Emergency Center	Concrete	Basement	0	Low	GOV2	1
SDFLT	Default School	Masonry	Slab on Grade	0	Low	EDU1	0.5
EFS1	School	Masonry	Slab on Grade	0	Low	EDU1	0.5
EFS2	University	Concrete	Slab on Grade	0	Low	EDU2	0.5

Some additional notes on the assumptions in Table 7-15:

- *Default Foundation Type:* The default values for EFFS, EFS1, EFS2, FDFLT, and SDFLT are Slab on Grade. All other essential facilities are assumed to have basements. The user can modify this field if their facility is represented incorrectly using the Hazus essential facility dialog.

- *First Floor Height Above Grade:* The default values for EFEO, EFFS, EFS1, and EFS2 are at grade. All other facilities are 3 feet above grade. The user can adjust this field using the Hazus essential facility dialog.

- *Number of Stories:* Default values for ESF1, EFHS, EFMC, EFFS, EFPS, and EFEO are all low-rise structures, and the EFHM, and EFHL are mid-rise. The user can adjust this field using the Hazus essential facility dialog.

- *Damage Functions:* Comparable damage functions from the General Building Stock are used to determine the estimated damage (percent) from which a loss of function for essential facilities can be developed. The user can change the damage functions in the analysis parameters dialog.

- *Functional Depth:* The general assumption is that when the depth of flooding reaches the functional depth, typically the facility is closed and people evacuated. In the case of some hospitals, this does not always mean the patients are evacuated, but the trauma center will typically refuse new patients.

7.3.6 Limitations

Essential facilities are represented by a single latitude/longitude point location, which may not fall precisely within the building's actual footprint. In addition, some essential facility records (e.g., hospitals, schools) may represent multiple buildings across a campus. Several defaults are provided in the data without verification: first floor heights, foundation types, building types, design levels, landslide, liquefaction, soil type, and water level are all values localized to the Study Region's county. Building types may not agree between models.

It should be noted that Hazus loads the national HIFLD Open data into individual inventory databases; differences between state abbreviation and spatial location can result in a small number of dropped records. Further, as noted above, multiple facilities may occur at the same building site for various essential facility types, such as when Elementary, Middle, and High Schools or Police Precincts share the same building, or when an EOC is co-located with a police or fire station. Each facility type may have its own HIFLD Open record and be present into multiple Hazus databases. This can result in an overestimate of exposure and subsequent losses. The use of number of students for estimating area and replacement value, when available for each school level, helps reduce the potential for overestimation in combined Elementary, Middle and High Schools. Some virtual schools may still make it into the dataset if "virtual" or a derivative is not used in the name; for these facilities, the area and replacement cost may not be accurate. If colleges or universities report virtual attendees only in their enrollment numbers, the area and replacement costs may also be overestimated.

Section 8. High Potential Loss Facilities

In Hazus, High Potential Loss (HPL) facilities are currently only considered in the Earthquake Model for hazard exposure only with the exception of military installations where loss methods are provided. HPL facilities include dams, nuclear power plants, and military installations. Only military facilities are currently modeled in Hazus for potential losses in the Earthquake Model, while other HPL facilities are assessed for exposure only to earthquake hazards. The inventory data required for HPL facilities include the geographical location of the facility.

Table 8-1 summarizes the status of the HPL facilities by data type, hazard, and sources in Hazus 6.0.

Table 8-1 Baseline High Potential Loss Database Summary

HPL Data Type	Data Element	Hazards	Hazus 6.0 Dataset Source	Geographic Coverage
Dams and Levees	Dams and Levees	Exposure Mapping Only	N/A	N/A
Nuclear Power Facility	Nuclear Power Facility	Exposure Mapping Only	N/A	N/A
Military Installations	Military Installations	EQ	N/A	N/A
Military Installations	Military Installations	EQ	Hazus Program Generated	PR
Military Installations	Military Installations	EQ	FEMA Advisory Base Flood Elevation Substantial Damage Estimation Mission from Hurricane's Irma/Maria	VI

The HPL classifications for dams, levees, nuclear power plants, and military installations are provided in Table 8-2. The dam classifications are based on the National Inventory of Dams database (FEMA, 1993). While dams, levees, and nuclear power facilities have no modeling capabilities in Hazus 6.0, military installations can be modeled in the Earthquake Model when additional data is provided, including location, classification, and replacement value. Currently, only Puerto Rico and the U.S. Virgin Islands have military installation data populated from previous updates. Each HPL facility should be treated on an individual basis by users who have sufficient expertise to evaluate the damage to such facilities. Required input to the damage evaluation module includes the following items:

- Earthquake capacity curves that represent median (typical) properties of the HPL facility structure, or a related set of engineering parameters, such as period, yield strength, and ultimate capacity, which may be used by seismic/structural engineering experts to select representative damage functions.

- Earthquake fragility curves for the HPL facility under consideration, or a related set of engineering parameters that can be used by seismic/structural engineering experts to select appropriate damage functions.

See the *Hazus Earthquake Model Technical Manual* (FEMA, 2024a) for more details.

Table 8-2 High Potential Loss Facilities Classifications

Hazus Label	General Classification	Specific Class
HPDA	Dams	Arch
HPDB	Dams	Buttress
HPDC	Dams	Concrete
HPDE	Dams	Earth
HPDG	Dams	Gravity
HPDM	Dams	Masonry
HPDR	Dams	Rock fill
HPDS	Dams	Stone
HPDT	Dams	Timber Crib
HPDU	Dams	Multi-Arch
HPDZ	Dams	Miscellaneous
HPLV	Levee	Levee
HPNP	Nuclear Power Facilities	Nuclear Power Facilities
HMI01	Military Installations	Barracks/Group Quarters
HMI02	Military Installations	Officer/Enlisted Quarters - Multi-Unit
HMI03	Military Installations	Officer/Enlisted Quarters - Detached
HMI04	Military Installations	Maintenance/Operations Shops
HMI05	Military Installations	Administrative Offices
HMI06	Military Installations	Mess Halls
HMI07	Military Installations	Officer/Enlisted Clubs
HMI08	Military Installations	Gymnasiums/Armory
HMI09	Military Installations	Gas/Services Stations
HMI10	Military Installations	PX/Retail Stores
HMI11	Military Installations	Arsenals
HMI12	Military Installations	Other

Section 9. Transportation Systems

Hazus includes modeling capabilities related to transportation systems. The Transportation Module and associated inventory data in Hazus includes the following: highways, railways, light rail, bus, ports, ferries, and airports. The transportation classification system used in the Hazus Methodology was developed to provide an ability to differentiate between different system components with substantially different damage and loss characteristics. All transportation system elements can be modeled by the Earthquake Model. In the Flood Model highway bridges are the only transportation system components analyzed by the software. Damage functions are included within the Hazus Flood Model for railway and light rail bridges; however, no analyses are performed in Hazus 6.0.

Table 9-1 summarizes the status of the transportation system spatial and tabular database elements by data type, hazard, and sources. Beginning in 2019, most of the transportation data were updated using datasets from HIFLD Open. Table 9-2 and Table 9-3 provide the valuation models used for the HIFLD-based Open datasets. Valuation models identified as “legacy” models are those developed during the original Hazus Earthquake or Flood Model development processes. The remaining discussion in this section provides more background into the different elements of each transportation system, Hazus classifications, and the Hazus valuation used for facility classes not currently modeled using HIFLD Open data.

Table 9-1 Baseline Transportation System Databases Summary

Transportation Data Type	Data Element	Hazards	Hazus 6.0 Dataset Date	Hazus 6.0 Dataset Source
Highway Segment Data	Highway Segment	EQ	2005	National Highway Planning Network
Highway Bridge Data	Highway Bridge	EQ, FL	2021	FHWA National Bridge Inventory (NBI)
Highway Tunnel Data	Highway Tunnel	EQ	Sept. 2019	HIFLD Open: Road Tunnels
Railway Segment Data	Railway Segment	EQ	Jun. 2022	HIFLD Open: Railroads. Segments that are abandoned (Name includes “abandoned”) have been omitted. The railway segment data set has been supplemented with data from HIFLD Open: Public Transit Routes, where Mode = “AR” (Alaska Railroad), “CR” (Commuter Rail), or “HR” (Heavy Rail), and Status is not “Closed.”
Railway Bridge Data	Railway Bridge	EQ	Apr. 2018	HIFLD Open: Railroad Bridges
Railway Tunnel Data	Railway Tunnel	EQ	2001	FHWA NBI

Transportation Data Type	Data Element	Hazards	Hazus 6.0 Dataset Date	Hazus 6.0 Dataset Source
Railway Facility Data	Railway Facility	EQ	2007	Bureau of Transportation Statistics
Light Rail Segment Data	Light Rail Segment	EQ	Sept. 2017	HIFLD Open: Public Transit Routes, where Mode = “LR” (Light Rail) or "SR” (Streetcar Rail). Segments that are abandoned (Name includes “abandoned”) have been omitted. The Public Transit Route data includes records for each named route; multiple routes may use the same segment of track, so track length and value may be over-estimated.
Light Rail Bridge Data	Light Rail Bridge	EQ, FL	2001	FHWA NBI
Light Rail Facility Data	Light Rail Facility	EQ	July 2020	HIFLD Open: Public Transit Stations, joined to HIFLD Open: Public Transit Routes, and where Mode = “LR” (Light Rail) or "SR” (Streetcar Rail). Records with Status = “Planned” have been omitted. Ground level streetcar rail facilities (GRD_EL = “GROUND"), assumed to be stops rather than stations, have been omitted.
Bus Data	Bus	EQ	Jan. 2022	HIFLD Open: Intermodal Passenger Connectivity Database where facility type = 2 and Modes Served = 1, or Modes Served = 2 where the second mode is Bike-Share. In order to exclude non-station bus stops, a list of key word exclusions has been developed reflecting common stop facility types, such as gas stations, lodging, retail, restaurants, and other non-station facilities (e.g., exclude if NAME includes “Chevron” or “Hilton”).
Port Data	Port	EQ	Jan. 2022	HIFLD Open: Port Facilities. Facility types other than "Dock" and "Marina" have been omitted.

Transportation Data Type	Data Element	Hazards	Hazus 6.0 Dataset Date	Hazus 6.0 Dataset Source
Ferry Data	Ferry	EQ	2007	USACE Institute for Water Resources (CEIWR) Navigation Data Center
Airport Facility Data	Airport Facility	EQ	May 2022	HIFLD Open: Aircraft Landing Facility. Facilities with Owner_type = "PR" (Private) have been omitted.
Airport Facility Data	Airport Facility	EQ	Apr. 2022	US DOT T-100 Domestic Market and Segment Data for flight arrival, departure and passenger data.

Table 9-2 Valuation Data for Transportation Elements

Element	Geographic Coverage	Valuation Approach
Highway Segments	All states; territory coverage limited to Puerto Rico	Uses updated values for 2019 of $6.668M/km for four lane major road and $3.334M/km for two lane urban streets.
Highway Bridge	All states; territory coverage limited to Puerto Rico	The 2018 square-footage cost table for each bridge class provided by Caltrans was escalated to 2021 based on CPI and is provided in Table 9-3. Costs are also adjusted for other states relative to California based on the 2022 State non-residential location factors (derived from average of county factors in each state, see Section 6.3).
Highway Tunnel	All states; territory coverage limited to Puerto Rico	Tunnel replacement costs are represented by the cost of the tunnel liner, scaled by actual/assumed tunnel diameter from a baseline cost of $24,600 per meter (in 2022 dollars) for a 6 meter diameter tunnel. Typical highway tunnel diameter of 10.6 meters assumed when no diameter data are available.
Railway Segment	All states; territory coverage limited to Puerto Rico	Replacement costs for rail segments in urban areas are based on U.S. data for aboveground projects from the Eno Center for Transportation Transit Capital Construction Database (Eno Center, 2020), using the proportion of rail construction project cost allocated to Guideway and Track Elements, plus an allocation for professional services; $20 million per km (escalated to 2021 dollars). For non-urban areas, a cost of $1.42 million per km (in 2021 dollars) has been utilized (National Academy of Sciences, 2015). All costs are localized by Census division (see Table 3-1) using cost factors developed from the available Eno Center data. Rail segments are identified as urban or non-urban based on the location of their centroid.
Railway Bridge	All states, except Hawaii; territory coverage limited to Puerto Rico	Uses legacy value of $5M, adjusted by State non-residential location factors (see Section 6.3). Chose not to escalate to 2021 since the value is already well above the source (G&E, 1994b) report recommendation and with the new dataset, a large range of bridges, including more minor structures are included.

Element	Geographic Coverage	Valuation Approach
Railway Tunnel	All states; territory coverage limited to Puerto Rico	Data derived from 2001 NBI by the original Hazus development team in 2003; valuation based on expert opinion. Uses legacy value of $10M. Did not escalate to 2019 since there is uncertainty in base year and conversion issues in the legacy data.
Railway Facility	All states; territory coverage limited to Puerto Rico	Uses legacy value of $2M for railroad stations from original Hazus development (1998), escalated to $3.2M in 2019; this cost also applies to default railway facilities.
Light Rail Segment	All states except Hawaii and Alaska; no territory coverage	Replacement costs for light rail segments, which are generally limited to major metropolitan areas, are the same as the urban railway segment replacement cost model described above. The Public Transit Route data includes records for each named route; multiple routes may use the same segment of track, so track length and value may be over-estimated.
Light Rail Bridge	All states; territory coverage limited to Puerto Rico	Data derived from 2001 NBI by the original Hazus development team in 2003; valuation based on expert opinion. Uses legacy data and value of $5M. Did not escalate to 2019 since there is uncertainty in base year and conversion issues in the legacy data.
Light Rail Tunnel	All states; territory coverage limited to Puerto Rico	Uses legacy data and value of $10M. Did not escalate to 2019 since there is uncertainty in base year and conversion issues in the legacy data.
Light Rail Facility	All states except Alaska and Hawaii; no territory coverage	Replacement cost models have been developed from the Eno Center for Transportation Transit Capital Construction Database (Eno Center, 2020), considering their grade or elevation. Costs have been escalated to 2021 as follows: below grade/underground stations - $248.45M, above grade/elevated stations - $59.82M, at grade stations - $5.71M. Currently available data are insufficient to generate regional location factors, so none have been applied.
Bus	All states; no territory coverage	Typical bus stations assumed to be approximately 10,000 square feet based on available recent construction project data assembled from a limited web search. Baseline replacement cost model for this size facility derived from replacement cost models, and assumed to be $1.9715M per facility (in 2022 dollars), adjusted by county-level non-residential location factors (see Section 6.3).
Port	All states, except DC; territory coverage limited to Puerto Rico	Uses legacy value of $2M from original Hazus development (1998), escalated to $3.3496M in 2021, adjusted by county non-residential location factors (see Section 6.3).
Ferry	All states; territory coverage limited to Puerto Rico	Uses legacy value of $1M for ferry passenger terminal from original Hazus development (1998), escalated to $1.58M in 2019.

Element	Geographic Coverage	Valuation Approach
Airport Facility	All states and territories	Large passenger airports area proxy is based on annual passenger volume (0.5 ft^2 per annual passenger) and 2022 COM4 ft. replacement value, adjusted by county non-residential location factors (see Section 6.3). Other urban facilities use Airport Terminal legacy value from original Hazus development ($8M in 1998, escalated to $13.3356M in 2021), while rural facilities use Hazus legacy value for Hangar facilities ($3.2M in 1998, escalated to $5.3M in 2021). Costs are also adjusted by county non-residential location factors (see Section 6.3).
Airport Runway	All states and territories	Runway replacement costs are based on runway area (length times width) and assumed pavement thickness, and are derived from replacement cost models. Typical airport runways are assumed to be 20 inches thick with replacement costs of $124.30 per square yard (in 2022 dollars), while runways for heliports and other facility types with lighter aircraft are assumed to be 6 inches thick with replacement costs of $51.80 per square yard. Costs are adjusted by county non-residential location factors (see Section 6.3).

Table 9-3 Highway Bridge Replacement Cost Model

Bridge Class[1]	$/Square Foot (2021)
HWB1	$636
HWB2	$583
HWB3	$424
HWB4	$504
HWB5	$398
HWB6	$398
HWB7	$504
HWB8	$318
HWB9	$424
HWB10	$292
HWB11	$318
HWB12	$583
HWB13	$583
HWB14	$742
HWB15	$583
HWB16	$742
HWB17	$398
HWB18	$398
HWB19	$504
HWB20	$398

Bridge Class[1]	$/Square Foot (2021)
HWB21	$504
HWB22	$371
HWB23	$424
HWB24	$583
HWB25	$636
HWB26	$795
HWB27	$795
HWB28	$318

[1]See Table 9-6 for Hazus Bridge Class Definitions.

9.1 Highway Transportation System

A highway system is composed of three components: highway segments, bridges, and tunnels. In this section, a brief description for each is provided.

- *Highway Segments*: Highway segments are classified as major roads or urban roads. Major roads include interstate and state highways and other roads with four lanes or more. Parkways are also classified as major roads. Urban roads include intercity roads and other roads with two lanes.
- *Bridges:* Bridges are classified based on the following structural characteristics:
    - Seismic Design
    - *Number of spans:* single vs. multiple span bridges
    - *Structure type*: concrete, steel, and others
    - *Pier type:* multiple column bents, single column bents, and pier walls
    - *Abutment type and bearing type:* monolithic vs. non-monolithic, high rocker bearings, low steel bearings, and neoprene rubber bearings
    - *Span continuity:* continuous, discontinuous (in-span hinges), and simply supported
- *Tunnels:* Tunnels are classified as bored/drilled or cut and cover.

Additional background information for bridges is required, since the seismic design of a bridge is considered in terms of the (1) spectrum modification factor, (2) strength reduction factor due to cyclic motion, (3) drift limits, and (4) the longitudinal reinforcement ratio.

This classification scheme incorporates various parameters that affect damage into fragility analysis and provides a means to obtain better fragility curves when data become available. A total of 28 classes (HWB1 through HWB28) have been defined this way, based on bridge characteristics found in the NBI. Table 9-4 and Table 9-5 summarize the key NBI characteristics used, while Table 9-6 presents the 28 bridge classes derived for Hazus with detailed values related to flood analysis. Year built from the NBI is used to classify as seismic if built in 1990 or later in California, and 1975 or later outside of California.

Table 9-4 Bridge Material Classes in National Bridge Inventory

Code	Description
1	Concrete
2	Concrete continuous
3	Steel
4	Steel continuous
5	Prestressed concrete
6	Prestressed concrete continuous
7	Timber
8	Masonry
9	Aluminum, Wrought Iron, or Cast
0	Other

Table 9-5 Bridge Types in National Bridge Inventory

Code	Description
01	Slab
02	Stringer/Multi-Beam or Girder
03	Girder and Floor Beam System
04	Tee Beam
05	Box Beam or Girders – Multiple
06	Box Beam or Girders – Single or Spread
07	Frame
08	Orthotropic
09	Truss – Deck
10	Truss – Thru
11	Arch – Deck
12	Arch – Thru
13	Suspension
14	Stayed Girder
15	Movable – Lift
16	Movable – Bascule
17	Movable – Swing
18	Tunnel
19	Culvert
20	Mixed Types (applicable only to approach spans)
21	Segmental Box Girder
22	Channel Beam
00	Other

The 28 bridge classes in Table 9-6 (HWB1 through HWB28) reflect the maximum number of combinations for “standard” bridge classes.

Some of the items in Table 9-6 need further descriptions. K3D value shown in table represents different equations that calculate a factor that modifies the piers' 2-dimensional capacity to allow for the 3-dimensional arch action in the deck. The *Hazus Earthquake Model Technical Manual* (FEMA, 2024a) includes the specific equations for the actual K3D values.

The Ishape item is a Boolean indicator for the Kshape factor. The Kshape factor is the modifier that converts cases for short periods to an equivalent spectral amplitude at T=1.0 second. When Ishape = 0, the Kshape factor does not apply. When Ishape = 1, the Kshape factor applies. The *Hazus Earthquake Model Technical Manual* (FEMA, 2022a) includes more information on applying the Kshape factor.

Table 9-6 Detailed Hazus Bridge Classification Scheme

Class	NBI Class	State	Year Built	# Spans	Length of Max. Span (meter)	Length less than 20 meters	K3D	Ishape	Design	Description
HWB1	All	Non-CA	< 1990	N/A	> 150	N/A	EQ1	0	Conventional	Major Bridge – Length > 150 meters
HWB1	All	CA	< 1975	N/A	> 150	N/A	EQ1	0	Conventional	Major Bridge – Length > 150 meters
HWB2	All	Non-CA	>= 1990	N/A	> 150	N/A	EQ1	0	Seismic	Major Bridge – Length > 150 meters
HWB2	All	CA	>= 1975	N/A	> 150	N/A	EQ1	0	Seismic	Major Bridge – Length > 150 meters
HWB3	All	Non-CA	< 1990	1	N/A	N/A	EQ1	1	Conventional	Single Span
HWB3	All	CA	< 1975	1	N/A	N/A	EQ1	1	Conventional	Single Span
HWB4	All	Non-CA	>= 1990	1	N/A	N/A	EQ1	1	Seismic	Single Span
HWB4	All	CA	>= 1975	1	N/A	N/A	EQ1	1	Seismic	Single Span
HWB5	101-106	Non-CA	< 1990	N/A	N/A	N/A	EQ1	0	Conventional	Multi-Col. Bent, Simple Support – Concrete
HWB6	101-106	CA	< 1975	N/A	N/A	N/A	EQ1	0	Conventional	Multi-Col. Bent, Simple Support – Concrete
HWB7	101-106	Non-CA	>= 1990	N/A	N/A	N/A	EQ1	0	Seismic	Multi-Col. Bent, Simple Support – Concrete
HWB7	101-106	CA	>= 1975	N/A	N/A	N/A	EQ1	0	Seismic	Multi-Col. Bent, Simple Support – Concrete
HWB8	205-206	CA	< 1975	N/A	N/A	N/A	EQ2	0	Conventional	Single Col., Box Girder – Continuous Concrete
HWB9	205-206	CA	>= 1975	N/A	N/A	N/A	EQ3	0	Seismic	Single Col., Box Girder – Continuous Concrete
HWB10	201-206	Non-CA	< 1990	N/A	N/A	N/A	EQ2	1	Conventional	Continuous Concrete
HWB10	201-206	CA	< 1975	N/A	N/A	N/A	EQ2	1	Conventional	Continuous Concrete

Class	NBI Class	State	Year Built	# Spans	Length of Max. Span (meter)	Length less than 20 meters	K3D	Ishape	Design	Description
HWB11	201-206	Non-CA	>= 1990	N/A	N/A	N/A	EQ3	1	Seismic	Continuous Concrete
HWB11	201-206	CA	>= 1975	N/A	N/A	N/A	EQ3	1	Seismic	Continuous Concrete
HWB12	301-306	Non-CA	< 1990	N/A	N/A	No	EQ4	0	Conventional	Multi-Col. Bent, Simple Support – Steel
HWB13	301-306	CA	< 1975	N/A	N/A	No	EQ4	0	Conventional	Multi-Col. Bent, Simple Support – Steel
HWB14	301-306	Non-CA	>= 1990	N/A	N/A	N/A	EQ1	0	Seismic	Multi-Col. Bent, Simple Support – Steel
HWB14	301-306	CA	>= 1975	N/A	N/A	N/A	EQ1	0	Seismic	Multi-Col. Bent, Simple Support – Steel
HWB15	402-410	Non-CA	< 1990	N/A	N/A	No	EQ5	1	Conventional	Continuous Steel
HWB15	402-410	CA	< 1975	N/A	N/A	No	EQ5	1	Conventional	Continuous Steel
HWB16	402-410	Non-CA	>= 1990	N/A	N/A	N/A	EQ3	1	Seismic	Continuous Steel
HWB16	402-410	CA	>= 1975	N/A	N/A	N/A	EQ3	1	Seismic	Continuous Steel
HWB17	501-506	Non-CA	< 1990	N/A	N/A	N/A	EQ1	0	Conventional	Multi-Col. Bent, Simple Support – Prestressed Concrete
HWB18	501-506	CA	< 1975	N/A	N/A	N/A	EQ1	0	Conventional	Multi-Col. Bent, Simple Support – Prestressed Concrete
HWB19	501-506	Non-CA	>= 1990	N/A	N/A	N/A	EQ1	0	Seismic	Multi-Col. Bent, Simple Support – Prestressed Concrete

Class	NBI Class	State	Year Built	# Spans	Length of Max. Span (meter)	Length less than 20 meters	K3D	Ishape	Design	Description
HWB19	501-506	CA	>= 1975	N/A	N/A	N/A	EQ1	0	Seismic	Multi-Col. Bent, Simple Support – Prestressed Concrete
HWB20	605-606	CA	< 1975	N/A	N/A	N/A	EQ2	0	Conventional	Single Col., Box Girder – Prestressed Continuous Concrete
HWB21	605-606	CA	>= 1975	N/A	N/A	N/A	EQ3	0	Seismic	Single Col., Box Girder – Prestressed Continuous Concrete
HWB22	601-607	Non-CA	< 1990	N/A	N/A	N/A	EQ2	1	Conventional	Continuous Concrete
HWB22	601-607	CA	< 1975	N/A	N/A	N/A	EQ2	1	Conventional	Continuous Concrete
HWB23	601-607	Non-CA	>= 1990	N/A	N/A	N/A	EQ3	1	Seismic	Continuous Concrete
HWB23	601-607	CA	>= 1975	N/A	N/A	N/A	EQ3	1	Seismic	Continuous Concrete
HWB24	301-306	Non-CA	< 1990	N/A	N/A	Yes	EQ6	0	Conventional	Multi-Col. Bent, Simple Support – Steel
HWB25	301-306	CA	< 1975	N/A	N/A	Yes	EQ6	0	Conventional	Multi-Col. Bent, Simple Support – Steel
HWB26	402-410	Non-CA	< 1990	N/A	N/A	Yes	EQ7	1	Conventional	Continuous Steel
HWB27	402-410	CA	< 1975	N/A	N/A	Yes	EQ7	1	Conventional	Continuous Steel
HWB28				N/A	N/A					All other bridges that are not classified

In constructing the Hazus bridge inventory, when a bridge is identified as having been remodeled, the bridge is reclassified from Conventional to Seismic bridge classes, using the date of reconstruction (the “remodel” date, which is used to overwrite the original year built) if that date is after the seismic design threshold year for each State (>=1975 for CA, and >=1990 for other states). Proposed remodeled dates in the future are not used. This assumes that retrofits upgrade the bridges from conventional to seismic design and the approach was verified with Caltrans. Otherwise Hazus uses the original year-built date to classify bridges. If a remodeled date is not available in the NBI, the default remodeled date in Hazus is updated with the year built date. This makes remodeled dates equal to year built dates in the Hazus inventory except for the cases where the remodeled date is in the future.

Table 9-7 includes the full Hazus Highway Classification. See Table 9-2 and Table 9-3 for information on replacement cost models.

Table 9-7 Hazus Highway System Classification

Label	Description
HDFLT	Default Highway Segment
HRD1	Major Roads (1 kilometer length, 4 lanes)
HRD2	Urban Roads (1 kilometer length, 2 lanes)
HDFLT	Default Bridge
HWB1	Major Bridge - Length > 150 meters (Conventional Design)
HWB2	Major Bridge - Length > 150 meters (Seismic Design)
HWB3	Single Span – (Not HWB1 or HWB2) (Conventional Design)
HWB4	Single Span – (Not HWB1 or HWB2) (Seismic Design)
HWB5	Concrete, Multi-Column Bent, Simple Support (Conventional Design), Non-California (Non-CA)
HWB6	Concrete, Multi-Column Bent, Simple Support (Conventional Design), California (CA)
HWB7	Concrete, Multi-Column Bent, Simple Support (Seismic Design)
HWB8	Continuous Concrete, Single Column, Box Girder (Conventional Design)
HWB9	Continuous Concrete, Single Column, Box Girder (Seismic Design)
HWB10	Continuous Concrete, (Not HWB8 or HWB9) (Conventional Design)
HWB11	Continuous Concrete, (Not HWB8 or HWB9) (Seismic Design)
HWB12	Steel, Multi-Column Bent, Simple Support (Conventional Design), Non-California (Non-CA)
HWB13	Steel, Multi-Column Bent, Simple Support (Conventional Design), California (CA)
HWB14	Steel, Multi-Column Bent, Simple Support (Seismic Design)
HWB15	Continuous Steel (Conventional Design)
HWB16	Continuous Steel (Seismic Design)
HWB17	PS Concrete Multi-Column Bent, Simple Support (Conventional Design), Non-California
HWB18	PS Concrete, Multi-Column Bent, Simple Support (Conventional Design), California (CA)
HWB19	PS Concrete, Multi-Column Bent, Simple Support (Seismic Design)
HWB20	PS Concrete, Single Column, Box Girder (Conventional Design)
HWB21	PS Concrete, Single Column, Box Girder (Seismic Design)

Label	Description
HWB22	Continuous Concrete, (Not HWB20/HWB21) (Conventional Design)
HWB23	Continuous Concrete, (Not HWB20/HWB21) (Seismic Design)
HWB24	Same definition as HWB12 except the bridge length is less than 20 meters
HWB25	Same definition as HWB13 except the bridge length is less than 20 meters
HWB26	Same definition as HWB15 except the bridge length is less than 20 meters and Non-CA
HWB27	Same definition as HWB15 except the bridge length is less than 20 meters and in CA
HWB28	All other bridges that are not classified (including wooden bridges)
HDFLT	Default Highway Tunnel
HTU1	Highway Bored/Drilled Tunnel
HTU2	Highway Cut and Cover Tunnel

For the Hazus highway segment data, the data provided in Hazus is the National Highway Planning Network created by the Federal Highway Administration (FHWA) and updated every three to six years, with the latest data published in 2022.

For flood analysis of highway bridges, the inventory data also includes a scour potential index from the source FHWA data. The *Hazus Flood Model Technical Manual* (FEMA, 2024d) includes more information on the scour potential index and how the Flood Model uses the scour for analyzing probability of failure or functionality. For highway bridges in the Flood Model, the results are probability of bridge failure and probability of bridge functionality, as well as estimates of direct economic loss.

9.2 Railway Transportation System

A railway system consists of four components: tracks/roadbeds, bridges, tunnels, and facilities. This section provides a brief description of each.

- *Tracks/Roadbeds:* Tracks/roadbeds refers to the assembly of rails, ties, and fastenings, and the ground on which they rest. Only one classification is adopted for these components. This classification is analogous to that of urban roads in highway systems.
- *Bridges:* Railway bridges are classified in a manner similar to steel and concrete highway bridges.
- *Tunnels:* Railway tunnels follow the same classification as highway tunnels. That is, they are classified either as bored/drilled tunnels, or cut and cover tunnels.
- *Railway system facilities:* Railway system facilities include urban and suburban stations, maintenance facilities, fuel facilities, and dispatch facilities.
    - Urban and suburban stations are generally key connecting hubs that are important for system functionality. In the western U.S., these buildings are mostly made of reinforced concrete shear walls or moment resisting steel frames, while in the eastern U.S., the small stations are mostly wood and the large ones are mostly masonry or braced steel frames.

- Maintenance facilities are housed in large structures that are not usually critical for system functionality as maintenance activities can be delayed or performed elsewhere. These building structures are often made of steel braced frames.

- Fuel facilities include buildings, tanks (anchored, unanchored, or buried), backup power systems (if available, anchored or unanchored diesel generators), pumps, and other equipment (anchored or unanchored). It should be mentioned that anchored equipment in general refers to equipment designed with special seismic tiedowns or tiebacks, while unanchored equipment refers to equipment designed with no special considerations other than the manufacturer's normal requirements. Some vibrating components, such as pumps, are bolted down regardless of concern for earthquakes. As used here, "anchored" means all components have been engineered to meet seismic criteria, which may include bracing (e.g., pipe or stack bracing) or flexibility requirements (e.g., flexible connections across separation joints) as well as anchorage. These definitions of anchored and unanchored apply to all transportation system components. Above ground tanks are typically made of steel with roofs also made of steel. Buried tanks are typically concrete wall construction with concrete roofs. The fuel facility functionality module was determined with a fault tree analysis considering redundancies and subcomponent behavior. Note that generic building damage functions were used in this fault tree analysis to develop the overall fragility curve of fuel facilities. In total, five types of fuel facilities are considered. These are: fuel facilities with or without anchored equipment, with or without backup power (all combinations), and fuel facilities with buried tanks.

- Dispatch facilities consist of buildings, backup power supplies (if available, anchored or unanchored diesel generators), and electrical equipment (anchored or unanchored). Damage functions for a generic reinforced concrete building with shear walls were used in this fault tree to develop the overall fragility curves for dispatch facilities. In total, four types of dispatch facilities are considered. These are dispatch facilities with or without anchored equipment and with or without backup power (all combinations).

Table 9-8 includes the full Hazus railway classification. See Table 9-2 and Table 9-3 for information on replacement cost models.

Table 9-8 Hazus Railway System Classification

Label	Description
Railway Tracks	
RDFLT	Default Track
RTR	Railway Tracks (per km)
Railway Bridges	
RDFLT	Default Railway Bridge
RLB1	Steel, Multi-Column Bent, Simple Support (Conventional Design), Non-California (Non-CA)
RLB2	Steel, Multi-Column Bent, Simple Support (Conventional Design), California (CA)
RLB3	Steel, Multi-Column Bent, Simple Support (Seismic Design)
RLB4	Continuous Steel (Conventional Design)
RLB5	Continuous Steel (Seismic Design)
RLB6	Same definition as HWB1 except the bridge length is less than 20 meters
RLB7	Same definition as HWB2 except the bridge length is less than 20 meters
RLB8	Same definition as HWB4 except the bridge length is less than 20 meters and Non-CA
RLB9	Same definition as HWB5 except the bridge length is less than 20 meters and in CA
RLB10	All other bridges that are not classified
Railway Facilities	
RDFLT	Default Railway Facility
RST	Rail Urban Station (with all building type options enabled)
RFF	Rail Fuel Facility (different combinations for with or without anchored components and/or with or without backup power)
RDF	Rail Dispatch Facility (different combinations for with or without anchored components and/or with or without backup power)
RMF	Rail Maintenance Facility (with all building type options enabled)
Railway Tunnels	
RDFLT	Default Railway Tunnel
RTU1	Rail Bored/Drilled Tunnel
RTU2	Rail Cut and Cover Tunnel

For the Hazus railway tunnel data, the data provided in Hazus is the NBI created by the FHWA in 2001. Currently, railway tunnels are no longer part of the NBI and are not updated in Hazus with the NBI. Limitations for its current use are that the locations of the tunnels from the 2001 dataset are not very accurate and are incomplete.

For the Hazus railway facility data, the data provided in Hazus is the Intermodal Terminal Facility Database created by the Bureau of Transportation Statistics in 2007. The dataset is updated annually with the latest data from 2022.

9.3 Light Rail Transportation System

Like railway systems, light rail systems consist of railway tracks/roadbeds, bridges, tunnels, maintenance facilities, and dispatch facilities. The only difference between rail and light rail systems is in the fuel facilities, which for light rail are direct current power substations. Light rail systems use electric power and have low voltage direct current power substations. The direct current power substations consist of electrical equipment, which converts the local electric utility alternating current power to direct current power. Two types of direct current power stations are considered. These are: (1) direct current power stations with anchored (seismically designed) components and (2) direct current power stations with unanchored (which are not seismically designed) components. Table 9-9 includes the full Hazus light rail system classification. See Table 9-2 for information on replacement cost models.

Table 9-7 Hazus Light Rail System Classification

Label	Description
LDFLT	Default Light Rail Track
LTR	Light Rail Track
LDFLT	Default Light Rail Bridges
LRB1	Steel, Multi-Column Bent, Simple Support (Conventional Design), Non-California (Non-CA)
LRB2	Steel, Multi-Column Bent, Simple Support (Conventional Design), California (CA)
LRB3	Steel, Multi-Column Bent, Simple Support (Seismic Design)
LRB4	Continuous Steel (Conventional Design)
LRB5	Continuous Steel (Seismic Design)
LRB6	Same definition as HWB1 except the bridge length is less than 20 meters
LRB7	Same definition as HWB2 except the bridge length is less than 20 meters
LRB8	Same definition as HWB4 except the bridge length is less than 20 meters and Non-CA
LRB9	Same definition as HWB5 except the bridge length is less than 20 meters and in CA
LRB10	All other bridges that are not classified
LDFLT	Default Light Rail Tunnel
LTU1	Light Rail Bored/Drilled Tunnel
LTU2	Light Rail Cut and Cover Tunnel
LDFLT	Default Light Rail Facilities
LDC	Light Rail Direct Current Substation
LDF	Light Rail Dispatch Facility (different combinations for with or without anchored components and/or with or without backup power)
LMF	Maintenance Facility (with all building type options enabled)

For the Hazus light rail data, the data provided in Hazus is from HIFLD and does not include all categories of light rail leaving gaps in light rail inventory.

For the Hazus light rail bridge data, the data provided in Hazus is from the NBI created by the FHWA in 2001. While the NBI does update their data annually, the light rail bridge data in Hazus is from 2001.

For the Hazus light rail tunnels, no data is provided, but it can be modeled using the Earthquake Model.

9.4 Bus Transportation System

A bus system consists mainly of four components: urban stations, fuel facilities, maintenance facilities, and dispatch facilities. This section provides a brief description of each.

- *Urban Stations:* These are mainly building structures.
- *Bus System Fuel Facilities:* Fuel facilities consist of fuel storage tanks, buildings, pump equipment and buried pipe, and sometimes backup power. The fuel facility functionality is determined with a fault tree analysis considering redundancies and sub-component behavior. The same sub-classes assumed for railway fuel facilities are assumed here.
- *Bus System Maintenance Facilities:* Maintenance facilities for bus systems are mostly of braced steel frame construction. The same classes assumed for railway maintenance facilities are assumed here.
- *Bus System Dispatch Facilities:* The same classes assumed for railway dispatch facilities above are assumed here.

Table 9-10 includes the Hazus bus system classification, including the legacy valuations still being used for elements not updated with HIFLD Open data.

Table 9-10 Hazus Bus System Classification

Label	Description	Hazus Valuation[1]
BDFLT	Default Bus facility	BPT value
BPT	Bus Urban Station (with all building type options enabled)	See Table 9-2
BFF	Bus Fuel Facility (different combinations for with or without anchored components and/or with or without backup power)	$150,000
BDF	Bus Dispatch Facility (different combinations for with or without anchored components and/or with or without backup power)	$400,000
BMF	Bus Maintenance Facilities (with all building type options enabled)	$1,300,000

[1]*Replacement cost data derived by original Hazus development team in 1998 from expert opinion.*

9.5 Port Transportation System

A port system consists of four components: waterfront structures, cranes/cargo handling equipment, fuel facilities, and warehouses. This section provides a brief description of each.

- *Waterfront Structures:* Waterfront structures include wharves (port embankments), seawalls (protective walls from erosion), and piers (break-water structures that form harbors). Waterfront structures typically are supported by wood, steel, or concrete piles. Many also have batter piles to resist lateral loads from wave action and impact of vessels. Seawalls are caisson walls retaining earth fill material.

- *Cranes and Cargo Handling Equipment:* These are large equipment items used to load and unload freight from vessels. These can be stationary or mounted on rails.

- *Port Fuel Facilities*: The fuel facility consists mainly of fuel storage tanks, buildings, pump equipment, piping, and sometimes backup power. These facilities are assumed to be equivalent to those for railway systems. The functionality of fuel systems is determined with a fault tree analysis, which considers redundancies and sub-component behavior.

- *Warehouses:* Warehouses are large buildings usually constructed of structural steel. In some cases, warehouses may be several hundred feet from the shoreline, while in other instances; they may be located on the wharf itself.

Table 9-11 includes the Hazus port and harbor system classification, including the legacy valuations still being used for elements not updated with HIFLD Open data.

Table 9-11 Hazus Port and Harbor System Classification

Label	Description	Hazus Valuation[1]
PDFLT	Default Port facility	See Table 9-2
PWS	Waterfront Structures	$1,500,000
PEQ1	Stationary Port Handling Equipment	$2,000,000
PEQ2	Rail Mounted Port Handling Equipment	$2,000,000
PWH	Port Warehouses (with all building type options enabled)	$1,200,000
PFF	Port Fuel Facility (different combinations for with or without anchored components and/or with or without backup power)	$2,000,000

[1]Replacement cost data derived by original Hazus development team in 1998 from expert opinion.

9.6 Ferry Transportation System

A ferry system consists of five components: waterfront structures, fuel facilities, maintenance facilities, dispatch facilities, and passenger terminals. This section provides a brief description of each.

- *Waterfront Structures:* These are the same as those described for port systems above.

- *Fuel Facilities:* These facilities are similar to those for port systems above but may be built for a smaller range of boat sizes associated with ferries as compared to ports.

- *Maintenance Facilities*: These are often steel braced frame structures, but other building types are possible.

- *Dispatch Facilities:* These are the same as those defined for railway systems.
- *Passenger Terminals:* These are often moment resisting steel frames, but other building types are possible.

Table 9-12 includes the Hazus ferry system classification, including the legacy valuations still being used for elements not updated with HIFLD Open data.

Table 9-12 Hazus Ferry System Classification

Label	Description	Hazus Valuation[1]
FDFLT	Ferry Default facility	FPT Value
FWS	Ferry Waterfront Structures	$1,500,000
FPT	Passenger Terminals (with all building type options enabled)	See Table 9-2
FFF	Ferry Fuel Facility (different combinations for with or without anchored components and/or with or without backup power)	$400,000
FDF	Ferry Dispatch Facility (different combinations for with or without anchored components and/or with or without backup power)	$200,000
FMF	Piers and Dock Facilities (with all building type options enabled)	$520,000

[1]Replacement cost data derived by original Hazus development team in 1998 from expert opinion.

The Hazus Ferry data is from USACE CEIWR Navigation Data Center, Ports and Waterways Division in 2007.

9.7 Airport Transportation System

An airport system consists of seven components: runways, control towers, fuel facilities, terminal buildings, maintenance facilities, hangar facilities, and parking structures. This section provides a brief description of each.

- *Runways:* This component consists of well-paved “flat and wide surfaces.”
- *Control Towers:* Control towers consist of a building and the necessary equipment for air traffic control and monitoring.
- *Fuel Facilities:* Previously defined in Section 9.2 of railway systems.
- *Terminal Buildings:* These are similar to urban stations of railway systems, but usually much larger in building area.
- *Maintenance and Hangar Facilities and Parking Structures:* These structures are mainly composed of buildings.

Table 9-13 includes the Hazus Airports Classifications including the legacy valuations still being used for elements not updated with HIFLD Open data.

Table 9-13 Hazus Airport Facility Systems Classifications

Label	Description	Hazus Valuation[1]
ADFLT	Airport Default facility	ATB value
ACT	Airport Control Tower (with all building type options enabled)	$5,000,000
ATB	Airport Terminal Building (with all building type options enabled)	See Table 9-2
APS	Airport Parking Structure (with all building type options enabled)	$1,400,000
AFF	Airport Fuel Facility (different combinations for with or without anchored components and/or with or without backup power)	$5,000,000
AMF	Airport Maintenance & Hangar Facility (with all building type options enabled)	$3,200,000
ARW	Airport Runway	See Table 9-2
AFO	Gliderport, Seaport, Stolport, Ultralight or Balloonport Facilities	$500,000
AFH	Heliport Facilities	$2,000,000

[1]Replacement cost data derived by original Hazus development team in 1998 from expert opinion.

9.8 Limitations

In summary, this section provided the latest status for Hazus data related to transportation systems. While many data sources have recently been updated from HIFLD Open sources, there are still some transportation systems with Hazus transportation data.

It should be noted that Hazus loads the national HIFLD Open data into individual inventory databases; differences between State abbreviation and spatial location can result in a small number of dropped records.

Hazus 6.0 captures facilities in water bodies (e.g., highway bridges) or nearby offshore (e.g., ports, ferries), where warranted, by assigning them to the nearest Census tract.

As noted above, the Public Transit Route data includes records for each named route; multiple routes may use the same segment of track, so track length and value may be over-estimated for individual segments and for light rail overall. That is, while losses for an individual route are expected to be reasonable, the exposure and losses for the entire system (i.e., multiple routes on the same segments) may be over-estimated.

Section 10. Utility Systems

Hazus includes limited modeling capabilities related to utility systems. The Utility Module is composed of the following six systems:

- Potable Water
- Wastewater
- Oil (crude and refined)
- Natural Gas
- Electric Power
- Communication

The classification system used in the Hazus Methodology was developed to be able to differentiate utility system components with substantially different damage and loss characteristics. All utility system elements can be modeled by the Earthquake Model. The Flood Model can model some of the utility system elements as shown in

Table 10-1 Baseline Utility Systems Databases Summary.

Table 10-1 summarizes the current status of the utility systems' spatial and tabular database elements by data type, hazard, sources. Table 10-2 and Table 10-3 provide supplemental information on the replacement cost models for the HIFLD-based datasets. Valuation models identified as "legacy" models are those developed during the original Hazus Earthquake or Flood Model development processes. Table 10-3 provides the power plant replacement cost model. The remaining discussion in this section will provide more background into the different elements of each utility system, Hazus classifications, and the Hazus valuation used for facility classes not currently modeled using HIFLD Open data.

Table 10-1 Baseline Utility Systems Databases Summary

Utilities Data Type	Data Element	Hazards	Hazus 6.0 Dataset Date	Hazus 6.0 Dataset Source
Potable Water Distribution Lines Data	Potable Water Distribution Lines	EQ	2021	TIGER data
Potable Water Facilities Data	Potable Water Facilities	EQ, FL	2001	Envirofacts Data Warehouse
Potable Water Pipelines Data	Potable Water Pipelines	EQ	2001	SC only, from South Carolina Emergency Management Division
Wastewater Distribution Lines Data	Wastewater Distribution Lines	EQ	2021	TIGER data

Utilities Data Type	Data Element	Hazards	Hazus 6.0 Dataset Date	Hazus 6.0 Dataset Source
Wastewater Facilities Data	Wastewater Facilities	EQ, FL	Apr. 2022	HIFLD Open: Wastewater Treatment Plants. Records for multiple permitted outflows have been de-duplicated based on field “Source_Id”.
Wastewater Pipelines Data	Wastewater Pipelines	EQ	2001	SC only, from South Carolina Emergency Management Division
Oil Facilities Data	Oil Facilities	EQ, FL	2001	Envirofacts Data Warehouse
Oil Pipelines Data	Oil Pipelines	EQ	2001	SC only, from South Carolina Emergency Management Division
Natural Gas Distribution Lines Data	Natural Gas Distribution Lines	EQ	2021	TIGER data
Natural Gas Facilities Data	Natural Gas Facilities	EQ, FL	Oct. 2020	HIFLD Open: Natural Gas Processing Plants. Processing plants with Status = “Inactive” are omitted.
Natural Gas Facilities Data	Natural Gas Facilities	EQ, FL	Jun. 2022	HIFLD Open: Natural Gas Compressor Stations. Compressor Stations with Status = “Closed” are omitted.
Natural Gas Pipelines Data	Natural Gas Pipelines	EQ	Aug, 2019	HIFLD Open: Natural Gas Pipelines
Electrical Power Facility Data	Electrical Power Facility	EQ	Dec. 2021	HIFLD Open: Power Plants. Plants with capacity less than 3 MW are omitted, as are Nuclear power plants. Plants with Status = “CN” (cancelled), “IP” (indefinitely postponed), “L” (regulatory approvals pending), “P” (proposed), “RE” (retired) and “T” (not under construction) are also omitted.
Communication Facility Data	Communication Facility	EQ	2001	Federal Communications Commission (FCC) Broadcast Auxiliary Microwave database

Table 10-2 Valuation Data for Utility Elements Developed from HIFLD Open Data

Element	Geographic Coverage	Valuation Approach
Wastewater Facilities	All states and territories.	Uses legacy value of \$60M for a small wastewater treatment plant, derived from ATC-13 (ATC, 1985), escalated to \$151.1M in 2021, adjusted by state non-residential location factors (see Section 6.3).
Natural Gas Facilities: Compressor Stations	All states except AK and DC; territory coverage limited to VI.	Replacement cost model based on data collected by the American Petroleum Institute (API, 2017): \$3,400 per hp (in 2021 dollars). When no capacity data are available, an average value of 15,355 hp derived from 2021 HIFLD Open data are applied. Compressor station-specific regional multipliers by API-defined regions are applied.
Natural Gas Facilities: Processing Plants	All states except AK and DC; territory coverage limited to VI.	Replacement cost model based on data collected by the American Petroleum Institute (API, 2017): \$720k per MMcf/day (in 2021 dollars). When no capacity data are available, an average value of 146 MMcf/day derived from 2021 HIFLD Open data are applied. The compressor station-specific regional multipliers are also applied to processing plants.
Natural Gas Pipelines	All states except AK, DC and HI; no territory coverage.	Replacement cost model based on data collected by the American Petroleum Institute (API, 2017): \$201k (in 2021 dollars) per inch-mile for transmission pipelines (TYPEPIPE = “interstate” and “intrastate”), assumed to be 30 inches in diameter, and \$168k per inch-mile (in 2021 dollars) for gathering pipelines (TYPEPIPE = ”gathering” and “other”), assumed to be 16 inches in diameter. Pipeline-specific regional multipliers for API-defined regions are applied.
Electrical Power Facility	All states except FL and HI; territory coverage limited to PR	Replacement cost models are derived from EIA generator construction cost data for 2019 (EIA, 2021), with \$/kW associated with energy source (see Table 10-3). Where plant capacity is not available, the average capacity by fuel type derived from 2021 HIFLD Open data, also provided in Table 10-3, is applied. Costs are localized by Census region using cost factors developed from the available EIA generator cost data.

Table 10-3 Power Plant Replacement Cost Model

EIA Power Plant Major Energy Source	$/kW (2021)	Average Capacity (MW) estimated from 2021 HIFLD Open data	Applicable "PRIM_FUEL" Classes in HIFLD Power Plant Data
Battery Storage	$3,151	16	"MWH"
Biomass	$3,078	26	"AB", "BLQ", "LFG", "MSW", "OBG", "OBL", "OBS", "SLW", "WDL", "WDS"
Coal	$4,405	818	"ANT", "BIT", "LIG", "RC", "SGC", "SUB", "WC"
Geothermal	$3,316	61	"GEO"
Hydro	$5,998	94	"WAT"
Natural Gas	$1,143	329	"BFG", "NG", OG"
Petroleum Liquids	$1,218	59	"DFO", "JF", "KER", "PC", "PG", "RFO", "RG", "SG", "WO"
Solar	$1,903	20	"SUN"
Waste Heat	$3,541	36	"OTH", "PUR", "TDF", "WH"
Wind	$1,474	97	"WND"
Average	$2,462	N/A	"NOT AVAILABLE"

10.1 Potable Water Systems

A potable water system typically consists of terminal reservoirs, water treatment plants, wells, pumping plants, storage tanks, and transmission and distribution pipelines. In this subsection, a brief description of each of these components is presented.

- *Terminal Reservoirs:* Terminal reservoirs are typically lakes (man-made or natural) and are usually located nearby and upstream of the water treatment plant. Vulnerability of terminal reservoirs and associated dams is not assessed in the Hazus loss estimation methodology. Therefore, even though reservoirs are an essential part of a potable water system, it is assumed in the analysis of water systems that the amount of water flowing into water treatment plants from reservoirs right after an earthquake is essentially the same as before the earthquake.

- *Transmission Aqueducts:* These transmission conduits are typically large size pipes (more than 20 inches in diameter) or channels (canals) that convey water from its source (reservoirs, lakes, and/or rivers) to the treatment plant.

  - Transmission pipelines are commonly made of concrete, ductile iron, cast iron, or steel. These could be elevated/at grade or buried. Elevated or at grade pipes are typically made of steel (welded or riveted), and they can run in single or multiple lines.

  - Canals are typically lined with concrete, mainly to avoid excessive loss of water by seepage and to control erosion. In addition to concrete lining, expansion joints are usually used to account for swelling and shrinkage under varying temperature and moisture conditions. Some damage to canals has occurred in historic earthquakes, but the modeling of damage to transmission aqueducts is outside the current scope of the methodology.

- *Water Treatment Plants (WTP):* Water treatment plants are generally composed of a number of physical and chemical unit processes connected in series, for the purpose of improving the water quality. A conventional WTP consists of a coagulation process, followed by a sedimentation process, and finally a filtration process. Alternately, a WTP can be regarded as a system of interconnected pipes, basins, and channels through which the water moves, and where the flow is governed by hydraulic principles. WTP are categorized as follows:

  - Small water treatment plants, with capacity ranging from 10 million gallons per day (mgd) to 50 mgd, are assumed to consist of a filter gallery with flocculation tanks (composed of paddles and baffles) and settling (or sedimentation) basins as the main components, as well as chemical tanks (needed in the coagulation and other destabilization processes), chlorination tanks, electrical and mechanical equipment, and elevated pipes.

  - Medium water treatment plants, with capacity ranging from 50 mgd to 200 mgd, are simulated by adding more redundancy to small treatment plants (i.e., twice as many flocculation, sedimentation, chemical, and chlorination tanks).

  - Large water treatment plants, with a capacity above 200 mgd, are simulated by adding even more redundancy to small treatment plants (i.e., three times as many flocculation, sedimentation, chemical, and chlorination tanks/basins).

  - Water treatment plants are also classified based on whether the subcomponents (equipment and backup power) are anchored or not.

- *Pumping Plants:* Pumping plants are usually composed of a building, one or more pumps, electrical equipment, and in some cases, backup power systems. Pumping plants are classified as either small (less than 10 mgd capacity), medium (10 to 50 mgd) or large (more than 50 mgd capacity). Pumping plants are also classified with respect to whether the subcomponents (equipment and backup power) are anchored or not. Anchored means equipment designed with special seismic tie downs and tiebacks, while unanchored means equipment installed with manufacturers' normal requirements.

- *Wells:* Wells typically have a capacity between 1 and 5 mgd. Wells are used in many cities as a primary or supplementary source of water supply. Wells include a shaft from the surface down to the aquifer, a pump to bring the water up to the surface, equipment used to treat the water, and sometimes a building, which encloses the well and equipment.

- *Water Storage Tanks:* Water storage tanks can be elevated steel, on ground steel (anchored/unanchored), on ground concrete (anchored/unanchored), buried concrete, or on ground wood tanks. Typical capacity of storage tanks is in the range of 0.5 mgd to 2 mgd.

- *Distribution Facilities and Distribution Pipes:* Distribution of water can be accomplished by gravity, or by pumps in conjunction with on-line storage. Except for storage reservoirs located at a much higher altitude than the area being served, distribution of water necessitates at least some pumping along the way. Typically, water is pumped at a relatively constant rate, with flow in excess of consumption being stored in elevated storage tanks. The stored water provides a reserve for fire flow and may be used for general-purpose flow should the electric power fail, or in case of pumping capacity loss.

Distribution pipelines are commonly made of concrete (prestressed or reinforced), asbestos cement, ductile iron, cast iron, steel, or plastic. The selection of material type and pipe size are based on the desired carrying capacity, availability of material at the time of construction, durability, and cost. Distribution pipes represent the network that delivers water to consumption areas. Distribution pipes may be further subdivided into primary lines, secondary lines, and small distribution mains. The primary or arterial mains carry flow from the pumping station to and from elevated storage tanks, and to the consumption areas, whether residential, industrial, commercial, or public. These lines are typically laid out in interlocking loops, and all smaller lines connecting to them are typically valved so that failure in smaller lines does not require shutting off the larger pipeline. Primary lines can be up to 36 inches in diameter. Secondary lines are smaller loops within the primary mains and run from one primary line to another. They provide a large amount of water for firefighting without excessive pressure loss. Small distribution lines represent the mains that supply water to the user and to the fire hydrants.

Table 10-4 includes the Hazus potable water system classification, including the legacy valuations still being used for elements not updated with HIFLD Open data.

Table 10-4 Hazus Potable Water System Classification

Label	Description	Hazus Valuation[1]
PDFLT	Default potable water pipes (per break)	$1,000
PWP1	Brittle Pipe (per break)	$1,000
PWP2	Ductile Pipe (per break)	$1,000
PDFLT	Default potable water facilities	PWTS value
PPPL	Large Pumping Plant (> 50 MGD) [different combinations for with or without anchored components]	$525,000
PPPM	Medium Pumping Plant (10 to 50 MGD) [different combinations for with or without anchored components]	$525,000
PPPS	Small Pumping Plant (< 10 MGD) [different combinations for with or without anchored components]	$150,000
PWE	Wells	$400,000
PSTAS	Above Ground Steel Tank	$800,000
PSTBC	Buried Concrete Tank	$1,500,000
PSTGC	On Ground Concrete Tank	$1,500,000
PSTGS	On Ground Steel Tank	$800,000
PSTGW	On Ground Wood Tank	$30,000

Label	Description	Hazus Valuation[1]
PWTL	Large WTP (> 200 MGD) [different combinations for with or without anchored components]	$360,000,000
PWTM	Medium WTP (50-200 MGD) [different combinations for with or without anchored components]	$100,000,000
PWTS	Small WTP (< 50 MGD) [different combinations for with or without anchored components]	$30,000,000
PCVS	Control Vaults and Control Stations	$50,000

[1]Replacement cost data for all facilities other than vaults were derived by original Hazus development team in 1998 from expert opinion; control vaults were added in 2003.

For the Hazus potable water distribution lines data, this data is based on total street length aggregated at the Census tract-level and comes from the 2021 TIGER data created by the U.S. Census Bureau. The data include Primary Roads (MTFCC = S1100), Secondary Roads (MTFCC = 1200), and Local Neighborhood Road/Rural Road/City Street (MTFCC = S1400). When a road link borders more than one tract, the length of the edges that make up the road link are equally distributed between the left and right tract that the link borders. It is assumed the water distribution pipe length equals the street length (80% being brittle pipe and 20% being ductile). The data is updated annually, with the latest update being from 2021.

For the Hazus potable water facilities data, this data is provided by the Envirofacts Data Warehouse from the U.S. Environmental Protection Agency (EPA). The data in Hazus was last updated in 2001.

For the Hazus potable water pipelines data, no baseline data was provided with Hazus, but user-input data can be modeled in the Earthquake Model.

For the Flood Model, Table 10-5 includes additional default values used for certain potable water data. Equipment Height represents the assumed flood elevation where electrical equipment is damaged. The Functional Depth represents the assumed flood elevation where the facility is closed and people evacuated, because the equipment is assumed to be flooded. It should be noted that the functional depth for utility systems components is not editable by the user and is not directly linked to the equipment height specified for each component in the inventory. As a result, if changes are made to the default equipment height assumptions in the inventory, functionality determinations will not reflect those changes. Similarly, the functional depth for utility systems and level of flood protection indicated in the inventory are also not linked in Hazus. If a system component is assigned a level of flood protection greater than or equal to the scenario return period, the component may be shown as non-functional regardless of its protection from the flood event.

Table 10-5 Potable Water System Classifications and Flood Model Default Parameters

Hazus Label	Specific Occupancy	FL Foundation Type	FL Equipment Height (ft)	FL Functional Depth (ft)	Comments
PDFLT	Default potable water pipes	N/A	N/A	N/A	Component is not analyzed in the flood model, mapping only capabilities.
PWP1	Brittle Pipe	N/A	N/A	N/A	Component is not analyzed in the flood model, mapping only capabilities.
PWP2	Ductile Pipe	N/A	N/A	N/A	Component is not analyzed in the flood model, mapping only capabilities.
PDFLT	Default potable water facilities	Slab on grade	0	4	
PPPL	Large Pumping Plant	Slab on grade	0	4	
PPPM	Medium Pumping Plant	Slab on grade	0	4	
PPPS	Small Pumping Plant	Slab on grade	0	4	
PWE	Wells	Slab on grade	0	4	
PSTAS	Above Ground Steel Tank	Slab on grade	80	80	
PSTBC	Buried Concrete Tank	Slab on grade	0	4	
PSTGC	On Ground Concrete Tank	Slab on grade	0	24	Tank floor at grade and tank does not float.
PSTGS	On Ground Steel Tank	Slab on grade	0	24	Tank floor at grade and tank does not float.
PSTGW	On Ground Wood Tank	Slab on grade	0	24	Tank floor at grade and tank does not float.
PWTL	Large WTP	Slab on grade	0	4	
PWTM	Medium WTP	Slab on grade	0	4	
PWTS	Small WTP	Slab on grade	0	4	
PCVS	Control Vaults and Control Stations	Slab on grade	0	1	Assumes entrance is at grade and not sealed.

10.2 Wastewater Systems

A wastewater system typically consists of collection sewers, interceptors, lift stations, and wastewater treatment plants. In this section, a brief description of each of these components is provided.

- *Collection Sewers*: Collection sewers are generally closed conduits that normally carry sewage with a partial flow. Collection sewers could be sanitary sewers, storm sewers, or combined sewers. Pipe materials used for potable water transportation may also be used for wastewater collection. The most commonly used sewer material is clay pipe manufactured with integral bell and spigot ends. These pipes range in size from 4 to 42 inches in diameter. Concrete pipes are mostly used for storm drains and for sanitary sewers carrying noncorrosive sewage (i.e., with organic materials). For the smaller diameter range, plastic pipes are also used.

- *Interceptors*: Interceptors are large diameter sewer mains. They are usually located at the lowest elevation areas. Pipe materials that are used for interceptor sewers are similar to those used for collection sewers.

- *Lift Stations:* Lift stations are important parts of the wastewater system. Lift stations serve to raise sewage over topographical rises. If the lift station is out of service for more than a short time, untreated sewage will either spill out near the lift station, or back up into the collection sewer system. Lift stations are classified as either small (capacity less than 10 mgd), medium (capacity 10 – 50 mgd), or large (capacity greater than 50 mgd). Lift stations are also classified as having either anchored or unanchored subcomponents.

- *Wastewater Treatment Plants (WWTP):* Three sizes of wastewater treatment plants are considered: small (capacity less than 50 mgd), medium (capacity between 50 and 200 mgd), and large (capacity greater than 200 mgd). Wastewater treatment plants have the same processes as water treatment plants, with the addition of secondary treatment subcomponents.

Table 10-6 presents the Hazus wastewater system classification, including the legacy valuations still being used for elements not updated with HIFLD Open data.

Table 10-6 Hazus Wastewater System Classification

Label	Description	Hazus Valuation[1]
Wastewater Pipelines		
WDFLT	Default wastewater pipe (per break)	$1,000
WWP1	Brittle Pipe (per break)	$1,000
WWP2	Ductile Pipe (per break)	$1,000
Wastewater Facilities		
WDFLT	Default wastewater facility	WWTS value
WWTL	Large WWTP (> 200 MGD) [different combinations for with or without anchored components]	$720,000,000
WWTM	Medium WWTP (50-200 MGD) [different combinations for with or without anchored components]	$200,000,000

Label	Description	Hazus Valuation[1]
WWTS	Small WWTP (< 50 MGD) [different combinations for with or without anchored components]	See Table 10-2 Valuation Data for Utility Elements Developed from HIFLD Open Data
WLSL	Large Lift Stations (> 50 MGD) [different combinations for with or without anchored components]	$1,050,000
WLSM	Medium Lift Stations (–0 MGD - 50 MGD) [different combinations for with or without anchored components]	$1,050,000
WLSS	Small Lift Stations (< 10 MGD) [different combinations for with or without anchored components]	$300,000
WWCV	Wastewater Control Vaults and Control Station	$50,000

[1]Replacement cost data for all facilities other than vaults were derived by original Hazus development team in 1998 from expert opinion; control vaults were added in 2003.

For the Hazus wastewater distribution lines data, this data is based on total street length aggregated at the Census tract-level and comes from the 2021 TIGER data created by the U.S. Census Bureau. The data include Primary Roads (MTFCC = S1100), Secondary Roads (MTFCC = 1200), and Local Neighborhood Road/Rural Road/City Street (MTFCC = S1400). When a road link borders more than one tract, the length of the edges that make up the road link are equally distributed between the left and right tract that the link borders. It is assumed the wastewater distribution pipe length equals 60% of the street length (60% being brittle pipe and 40% being ductile). The data is updated annually with the latest one from 2021.

For the Hazus wastewater pipelines data, no baseline data is provided in Hazus, but user-input data can be modeled in the Earthquake Model.

For the Flood Model, Table 10-7 includes additional default values used for certain wastewater data. Equipment Height represents the assumed flood elevation where electrical equipment is damaged. The Functional Depth represents the assumed flood elevation where the facility is closed, and people evacuated, because the equipment is assumed to be flooded. It should be noted that the functional depth for utility systems components is not editable by the user and is not directly linked to the equipment height specified for each component in the inventory. As a result, if changes are made to the default equipment height assumptions in the inventory, functionality determinations will not reflect those changes. Similarly, the functional depth for utility systems and level of flood protection indicated in the inventory are also not linked in Hazus. If a system component is assigned a level of flood protection greater than or equal to the scenario return period, the component may be shown as non-functional regardless of its protection from the flood event.

Table 10-7 Wastewater Classifications and Flood Model Default Parameters

Hazus Label	Specific Occupancy	FL Foundation Type	FL Equipment Height (ft)	FL Functional Depth (ft)	Comments
WDFLT	Default wastewater pipe	N/A	N/A	N/A	Component is not analyzed in the flood model, mapping only capabilities.
WWP1	Brittle Pipe	N/A	N/A	N/A	Component is not analyzed in the flood model, mapping only capabilities.
WWP2	Ductile Pipe	N/A	N/A	N/A	Component is not analyzed in the flood model, mapping only capabilities.
WDFLT	Default wastewater facility	Slab on grade	0	4	
WWTL	Large WWTP	Slab on grade	0	4	
WWTM	Medium WWTP	Slab on grade	0	4	
WWTS	Small WWTP	Slab on grade	0	4	
WLSL	Large Lift Stations	Slab on grade	0	4	
WLSM	Medium Lift Stations	Slab on grade	0	4	
WLSS	Small Lift Stations	Slab on grade	0	4	
WWCV	Wastewater Control Vaults and Control Station	Slab on grade	0	1	Assumes entrance is at grade and is not sealed.

10.3 Oil Systems

An oil system typically consists of refineries, pumping plants, tank farms, and pipelines. In this section, a brief description of each of these components is provided.

- *Refineries:* Refineries are an important part of an oil system. They process crude oil before it can be used. Although the supply of water is critical to the functioning of a refinery, it is assumed in the methodology that an uninterrupted supply of water is available to the refinery. Two sizes of refineries are considered: small and medium/large:
    - Small refineries (capacity less than 100,000 barrels per day) are assumed to consist of steel tanks on grade, stacks, other electrical and mechanical equipment, and elevated pipes. Stacks are essentially tall cylindrical chimneys.

  - Medium and large refineries (capacity of 100,000 to 500,000 barrels per day and more than 500,000 barrels per day, respectively) are simulated by adding more redundancy to small refineries (i.e., twice as many tanks, stacks, elevated pipes).

- *Oil Pipelines:* Oil pipelines are used for the transportation of crude oil over long distances. About 75% of the crude oil is transported throughout the United States by pipelines. A large segment of industry and millions of people could be severely affected by the disruption of crude oil supplies. Rupture of crude oil pipelines could lead to pollution of land and rivers. Pipelines are typically made of mild steel with submerged arc welded joints, although older gas welded steel pipe may be present in some systems. Buried pipelines are considered to be vulnerable to Peak Ground Velocity (PGV) and Permanent Ground Deformation (PGD).

- *Pumping Plants:* Pumping plants serve to maintain the flow of oil in cross-country pipelines. Pumping plants usually use two or more pumps. Pumps can be of either centrifugal or reciprocating type. However, no differentiation is made between these two types of pumps in the analysis of oil systems. Pumping plants are classified as having either anchored or unanchored subcomponents.

- *Tank Farms:* Tank farms are facilities that store fuel products. They include tanks, pipes, and electrical components. Tank farms are classified as having either anchored or unanchored subcomponents.

Table 10-8 includes the Hazus oil system classification, including the legacy valuations still being used for elements not updated with HIFLD Open data.

Table 10-8 Hazus Oil System Classification

Label	Description	Hazus Valuation[1]
Oil Pipelines		
ODFLT	Default oil pipeline (per break)	$1,000
OIP1	Welded Steel Pipe with Gas Welded Joints (per break)	$1,000
OIP2	Welded Steel Pipe with Arc Welded Joints (per break)	$1,000
Oil Facilities		
ODFLT	Default oil facility	ORFS value
ORFL	Large Refinery (> 500,000 lb/day) [different combinations for with or without anchored components]	$750,000,000
ORFM	Medium Refinery (1–0,000 - 500,000 lb/day) [different combinations for with or without anchored components]	$750,000,000
ORFS	Small Refinery (< 100,000 lb/day) [different combinations for with or without anchored components]	$175,000,000
OPP	Pumping Plant [different combinations for with or without anchored components]	$1,000,000
OTF	Tank Farms with Anchored Tanks [different combinations for with or without anchored components]	$2,000,000
OCV	Oil Control Vaults and Control Station	$50,000

[1]Replacement cost data for all facilities other than vaults were derived by original Hazus development team in 1998 from expert opinion; vaults were added in 2003.

For the Hazus oil facilities data, the data are provided by the Envirofacts Data Warehouse from EPA. This data is updated annually with the latest one from 2001.

For the Hazus oil pipelines data, no baseline data are provided in Hazus, but user-input data can be modeled in the Earthquake Model.

For the Flood Model, Table 10-9 includes additional default values used for certain oil system data. Equipment Height represents the assumed flood elevation where electrical equipment is damaged. The Functional Depth represents the assumed flood elevation where the facility is closed and people evacuated, because the equipment is assumed to be flooded. It should be noted that the functional depth for utility systems components is not editable by the user and is not directly linked to the equipment height specified for each component in the inventory. As a result, if changes are made to the default equipment height assumptions in the inventory, functionality determinations will not reflect those changes. Similarly, the functional depth for utility systems and level of flood protection indicated in the inventory are also not linked in Hazus. If a system component is assigned a level of flood protection greater than or equal to the scenario return period, the component may be shown as non-functional regardless of its protection from the flood event.

Table 10-9 Oil System Classifications and Flood Model Default Parameters

Hazus Label	Specific Occupancy	FL Foundation Type	FL Equipment Height (ft)	FL Functional Depth (ft)	Comments
ODFLT	Default oil pipeline	N/A	N/A	N/A	Component is not analyzed in the flood model, mapping only capabilities.
OIP1	Welded Steel Pipe with Gas Welded Joints	N/A	N/A	N/A	Component is not analyzed in the flood model, mapping only capabilities.
OIP2	Welded Steel Pipe with Arc Welded Joints	N/A	N/A	N/A	Component is not analyzed in the flood model, mapping only capabilities.
ODFLT	Default oil facility	Slab on grade	0	4	
ORFL	Large Refinery	Slab on grade	0	4	
ORFM	Medium Refinery	Slab on grade	0	4	
ORFS	Small Refinery	Slab on grade	0	4	
OPP	Pumping Plant	Slab on grade	0	0	
OTF	Tank Farms	Slab on grade	0	0	Assume tank bottom is at grade and tanks will not float.

Hazus Label	Specific Occupancy	FL Foundation Type	FL Equipment Height (ft)	FL Functional Depth (ft)	Comments
OCV	Oil Control Vaults and Control Station	Slab on grade	0	1	Assumes entrance is at grade and is not sealed.

10.4 Natural Gas Systems

A natural gas system typically consists of compressor stations and pipelines, as defined below:

- *Compressor Stations*: Compressor stations serve to maintain the flow of gas in pipelines. Compressor stations consist of either centrifugal or reciprocating compressors. However, no differentiation is made between these two types of compressors in the analysis of natural gas systems. Compressor stations are categorized as having either anchored or unanchored subcomponents. The compressor stations are similar to pumping plants in oil systems.

- *Natural Gas Pipelines*: Natural gas pipelines are typically made of mild steel with submerged arc-welded joints, although older lines may have gas-welded joints. These are used for the transportation of natural gas over long distances. Many industries and residents could be severely affected should disruption of natural gas supplies occur.

Table 10-10 presents the Hazus natural gas system classification, including the legacy valuations still being used for elements not updated with HIFLD Open data.

Table 10-10 Hazus Natural Gas System Classification

Label	Description	Hazus Valuation[1]
Buried Pipelines		
GDFLT	Default natural gas pipeline	See Table 10-2
NGP1	Welded Steel Pipe with Gas Welded Joints	See Table 10-2
NGP2	Welded Steel Pipe with Arc Welded Joints	See Table 10-2
Natural Gas Facilities		
GDFLT	Default natural gas facilities (including Processing Plants)	See Table 10-2
NGC	Compressor Stations [different combinations for with or without anchored components]	See Table 10-2
NGCV	Control Valves and Control Stations	$50,000

[1]Replacement cost data for all facilities other than vaults were derived by original Hazus development team in 1998 from expert opinion; control vaults were added in 2003.

For the Hazus natural gas distribution lines data, this data is based on total street length aggregated at the Census tract-level and comes from the 2021 TIGER data created by the U.S. Census Bureau. The data include Primary Roads (MTFCC = S1100), Secondary Roads (MTFCC = 1200), and Local Neighborhood Road/Rural Road/City Street (MTFCC = S1400). When a road link borders more than one tract, the length of the edges that make up the road link are equally distributed between the left and right tract that the link borders. It is assumed the gas distribution pipe length equals 40% of the street length (10% being brittle pipe and 90% being ductile). The data is updated annually with the latest one from 2021.

For the Flood Model, Table 10-11 includes additional default values used for certain natural gas system data. Equipment Height represents the assumed flood elevation where electrical equipment is damaged. The Functional Depth represents the assumed flood elevation where the facility is closed and people evacuated, because the equipment is assumed to be flooded. It should be noted that the functional depth for utility systems components is not editable by the user and is not directly linked to the equipment height specified for each component in the inventory. As a result, if changes are made to the default equipment height assumptions in the inventory, functionality determinations will not reflect those changes. Similarly, the functional depth for utility systems and level of flood protection indicated in the inventory are also not linked in Hazus. If a system component is assigned a level of flood protection greater than or equal to the scenario return period, the component may be shown as non-functional regardless of its protection from the flood event.

Table 10-11 Natural Gas System Classifications and Flood Model Default Parameters

Hazus Label	Specific Occupancy	FL Foundation Type	FL Equipment Height (ft)	FL Functional Depth (ft)	Comments
GDFLT	Default natural gas pipeline	N/A	N/A	N/A	Component is not analyzed in the flood model, mapping only capabilities.
NGP1	Welded Steel Pipe with Gas Welded Joints	N/A	N/A	N/A	Component is not analyzed in the flood model, mapping only capabilities.
NGP2	Welded Steel Pipe with Arc Welded Joints	N/A	N/A	N/A	Component is not analyzed in the flood model, mapping only capabilities.
GDFLT	Default natural gas facility	Slab on grade	0	4	
NGC	Compressor Stations	Slab on grade	0	4	
NGCV	Control Valves and Control Stations	Slab on grade	0	1	Assumes entrance is at grade and is not sealed.

10.5 Electric Power Systems

The components of an electric power system considered in the loss estimation methodology are substations, distribution circuits, and generation plants. In this section, a brief description of each of these components is presented.

- *Substations*: An electric substation is a facility that serves as a source of energy supply for the local distribution area in which it is located. Substations can be entirely enclosed in buildings, where all the equipment is assembled into one metal clad unit. Other substations have step-down transformers, high voltage switches, oil circuit breakers, and lightning arrestors located outside the substation building. In the current loss estimation methodology, only transmission (138 kV to 765 kV or higher) and subtransmission (34.5 kV to 161 kV) substations are considered. These will be classified as high voltage (350 kV and above), medium voltage (150 kV to 350 kV) and low voltage (34.5 kV to 150 kV) and will be referred to as Large (500 kV) substations, Medium (230kV) substations, and Small (115 kV) substations, respectively. The classification is also a function of whether the subcomponents are anchored or typical (unanchored), as defined in Section 9.2. A substation has the following main functions:

- Change or switch voltage from one level to another.
- Provide points where safety devices such as disconnect switches, circuit breakers, and other equipment can be installed.
- Regulate voltage to compensate for system voltage changes.
- Eliminate lightning and switching surges from the system.
- Convert alternating current to direct current and direct current to alternating current, as needed.
- Change frequency, as needed.

- *Distribution Circuits*: The distribution system is divided into circuits. A distribution circuit includes poles, wires, in-line equipment and utility-owned equipment at customer sites. A distribution circuit also includes above ground and underground conductors. Distribution circuits either consist of anchored or unanchored components.

- *Generation Plants*: Generation plant subcomponents include diesel generators, turbines, racks and panels, boilers and pressure vessels, and the buildings in which these are housed. The size of the generation plant is determined from the number of Megawatts (MW) of electric power that the plant can produce under normal operations. Small generation plants have a generation capacity of less than 100 MW. Medium generation plants have a capacity between 200 and 500 MW, while Large plants have a capacity greater than 500 MW. Fragility curves for generation plants with anchored versus unanchored subcomponents are presented. These plants produce alternating current (AC) and may be any of the types listed below. Fossil fuels are either coal, oil, or natural gas.

  - Hydroelectric
  - Steam turbine (fossil fuel fired or nuclear)
  - Combustion turbine (fossil fuel fired)
  - Geothermal
  - Solar
  - Wind
  - Compressed air

Table 10-12 includes the Hazus electric power system classification, including the legacy valuations that are still being used for elements that have not been updated with HIFLD Open data.

Table 10-12 Hazus Electric Power Facilities System Classification

Label	Description	Hazus Valuation[1]
EDFLT	Default electric power facilities	use EPPS value
ESSL	Low Voltage (115 kV) Substation [different combinations for with or without anchored components]	$10,000,000
ESSM	Medium Voltage (230 kV) Substation [different combinations for with or without anchored components]	$20,000,000
ESSH	High Voltage (500 kV) Substation [different combinations for with or without anchored components]	$50,000,000
EDC	Distribution Circuits (either Seismically Designed Components or Standard Components)	$3,000
EPPL	Large Power Plants (> 500 MW) [different combinations for with or without anchored components]	See Table 10-2 Valuation Data for Utility Elements Developed from HIFLD Open Data
EPPM	Medium Power Plant (100 - 500 MW) [different combinations for with or without anchored components]	See Table 10-2 Valuation Data for Utility Elements Developed from HIFLD Open Data
EPPS	Small Power Plants (< 100 MW) [different combinations for with or without anchored components]	See Table 10-2 Valuation Data for Utility Elements Developed from HIFLD Open Data

[1]Replacement cost models were derived by original Hazus development team in 1998 from expert opinion.

For the Hazus electric power facilities data, the data are provided from the HIFLD Open Data: Power Plants (2021). This included data from all 50 states as well as the District of Columbia and Puerto Rico.

For the Flood Model, Table 10-13 includes additional default values used for certain electric power system data. Equipment Height represents the assumed flood elevation where electrical equipment is damaged. The Functional Depth represents the assumed flood elevation where the facility is closed and people evacuated, because the equipment is assumed to be flooded. It should be noted that the functional depth for utility systems components is not editable by the user and is not directly linked to the equipment height specified for each component in the inventory. Analysis is not performed for Electric Power Systems but can be mapped for reference.

Table 10-13 Electric Power System Classifications and Flood Model Default Parameters

Hazus Label	Specific Occupancy	FL Foundation Type	FL Equipment Height (ft)	FL Functional Depth (ft)	Comments
EDFLT	Default electric power facilities	Slab on grade	0	4	Component is not analyzed in the flood model, mapping only capabilities.
ESSL	Low Voltage Substation	Slab on grade	0	4	Component is not analyzed in the flood model, mapping only capabilities.
ESSM	Medium Voltage Substation	Slab on grade	0	4	Component is not analyzed in the flood model, mapping only capabilities.
ESSH	High Voltage Substation	Slab on grade	0	4	Component is not analyzed in the flood model, mapping only capabilities.
EDC	Distribution Circuits	N/A	N/A	N/A	Component is not analyzed in the flood model, mapping only capabilities.
EPPL	Large Power Plant	Slab on grade	0	4	Component is not analyzed in the flood model, mapping only capabilities.
EPPM	Medium Power Plant	Slab on grade	0	4	Component is not analyzed in the flood model, mapping only capabilities.
EPPS	Small Power Plant	Slab on grade	0	4	Component is not analyzed in the flood model, mapping only capabilities.

10.6 Communication Systems

The major components of a communication system are:

- Central offices and broadcasting stations (this includes all subcomponents such as central switching equipment).
- Transmission lines (these include all subcomponents such as equipment used to connect central office to end users).
- Cabling (low-capacity links).

Central offices and broadcasting stations are the only components of the communication system considered in this section.

A communication facility consists of a building (a generic type is assumed in the methodology), central switching equipment (i.e., digital switches, anchored or unanchored), and back-up power supply (i.e., diesel generators or battery generators, anchored or unanchored) that may be needed to supply the requisite power to the center in case of loss of off-site power.

Table 10-14 includes the Hazus communication system classification, including the legacy valuations still being used for elements not updated with HIFLD Open data.

Table 10-14 Hazus Communication Facilities System Classification

Label	Description	Hazus Valuation[1]
CDFLT	Default communication facility	CBO value
CCO	Central Offices (different combinations for with or without anchored components and/or with or without backup power)	$5,000,000
CBR	AM or FM radio stations or transmitters	$2,000,000
CBT	TV stations or transmitters	$2,000,000
CBW	Weather stations or transmitters	$2,000,000
CBO	Other stations or transmitters	$2,000,000
CCSV	Control Vault (FL only)	$50,000

[1]Replacement cost models for all facilities other than vaults were derived by original Hazus development team in 1998 from expert opinion; control vaults were added in 2003.

The Hazus communication facility data came from the FCC Broadcast Auxiliary Microwave database from 2001. Communication facilities are not analyzed in the flood model but are able to be mapped.

10.7 Limitations

In summary, this section provided the latest status for Hazus data related to utility systems. While some data sources have recently been updated from HIFLD Open sources, still over half of the utility system elements make use of some Hazus utility data.

It should be noted that Hazus loads the national HIFLD Open data into individual inventory databases; differences between State abbreviation and spatial location can result in a small number of dropped records.

Hazus 6.0 captures facilities in water bodies or nearby offshore (e.g., wastewater outfalls), where warranted, by assigning them to the nearest Census tract.

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Appendix A. Building Stock Mapping Scheme Tables

Table A-1 Distribution Percentage of Floor Area for Specific Occupancy Classes within each General Occupancy Class

Specific Occupancy Class Label	Specific Occupancy Class	RES	COM	IND	AGR	REL	GOV	EDU
RES1	Single-Family Dwelling	*						
RES2	Mobile Home	*						
RES3	Multi-Family Dwelling	*						
RES4	Temporary Lodging	*						
RES5	Institutional Dormitory	*						
RES6	Nursing Home	*						
COM1	Retail Trade		*					
COM2	Wholesale Trade		*					
COM3	Personal and Repair Services		*					
COM4	Professional/Technical		*					
COM5	Banks		*					
COM6	Hospital		*					
COM7	Medical Office/Clinic		*					
COM8	Entertainment & Recreation		*					
COM9	Theaters		*					
COM10	Parking		*					
IND1	Heavy			*				
IND2	Light			*				
IND3	Food/Drugs/Chemicals			*				
IND4	Metals/Minerals Processing			*				
IND5	High Technology			*				
IND6	Construction			*				
AGR1	Agriculture				100			
REL1	Church					100		
GOV1	General Services						*	
GOV2	Emergency Response						*	
EDU1	Schools							*
EDU2	Colleges/Universities							*

**The relative distribution varies by Census tract and is computed directly from the specific occupancy class square footage inventory. For Agriculture (AGR) and Religion (REL) there is only one specific occupancy class, therefore the distribution is always 100%.*

Table A-1. Distribution Percentage of Floor Area for Specific Building Types (SBTs) within each Building Occupancy Class, Low-Rise, Pre-1950, West Coast (after ATC-13, 1985) [1][2]

Specific Occup. Class	W1	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML	MH
RES2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
RES3	100	0	11	11	11	0	67	0	50	50	0	0	10	0	90	100
RES4	100	0	8	4	8	4	76	0	84	16	0	0	18	0	82	0
RES5	100	0	71	14	0	14	0	0	61	39	0	0	22	0	78	0
RES6	100	0	0	0	67	0	33	0	100	0	0	0	67	0	33	0
COM1	0	100	6	0	19	10	65	0	94	6	0	0	21	0	79	0
COM2	0	100	6	0	8	4	82	0	82	5	14	0	25	10	65	0
COM3	0	100	4	4	13	0	78	0	88	0	13	0	20	0	80	0
COM4	0	100	8	4	12	0	76	0	100	0	0	0	21	0	79	0
COM5	0	100	8	4	12	0	76	0	100	0	0	0	21	0	79	0
COM6	0	100	17	7	38	0	38	0	90	7	3	0	82	0	18	0
COM7	0	100	19	7	37	0	37	0	83	11	6	0	67	0	33	0
COM8	0	100	35	3	6	9	47	0	87	13	0	0	19	4	78	0
COM9	0	100	48	17	0	0	36	0	87	13	0	0	33	0	67	0
COM10	0	0	0	24	0	24	53	0	84	14	0	2	40	20	40	0
IND1	0	100	48	21	3	3	25	0	64	32	5	0	29	14	57	0
IND2	0	100	22	13	35	2	29	0	89	6	6	0	13	0	87	0
IND3	0	100	35	15	6	6	38	0	92	0	8	0	13	0	87	0
IND4	0	100	41	21	12	3	22	0	89	0	11	0	9	27	64	0
IND5	0	100	62	15	15	0	9	0	71	4	20	4	88	0	12	0
IND6	0	100	9	6	30	0	55	0	53	47	0	0	10	0	90	100
AGR1	100	0	14	10	67	0	10	0	100	0	0	0	0	7	93	0
REL1	100	0	26	0	6	0	68	0	75	25	0	0	30	0	70	0
GOV1	0	100	29	4	11	14	43	0	91	9	0	0	35	0	65	0
GOV2	100	0	0	0	0	100	0	0	100	0	0	0	19	0	81	0

Specific Occup. Class	W1	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML	MH
EDU1	100	0	18	0	9	9	64	0	84	16	0	0	29	0	71	0
EDU2	100	0	14	29	0	14	43	0	100	0	0	0	47	12	42	0

[1]Refer to Table A-22 for states' classifications. For "Res1" Distribution, refer to Table A-17.
[2] Unreinforced SBTs URM, C3 and S5 are not allowed in West Coast Region where Design Levels are higher than Pre-Code.

Table A-2. Distribution Percentage of Floor Area for Specific Building Types within each Building Occupancy Class, Low-Rise, 1950-1970, West Coast (after ATC-13, 1985) [1][2]

Specific Occup. Class	W1	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML	MH
RES2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
RES3	100	0	11	11	11	0	67	0	50	50	0	0	10	0	90	100
RES4	100	0	8	4	8	4	76	0	84	16	0	0	18	0	82	0
RES5	100	0	71	14	0	14	0	0	61	39	0	0	22	0	78	0
RES6	100	0	0	0	67	0	33	0	100	0	0	0	67	0	33	0
COM1	0	100	6	0	19	10	65	0	94	6	0	0	21	0	79	0
COM2	0	100	6	0	8	4	82	0	82	5	14	0	25	10	65	0
COM3	0	100	4	4	13	0	78	0	88	0	13	0	20	0	80	0
COM4	0	100	8	4	12	0	76	0	100	0	0	0	21	0	79	0
COM5	0	100	8	4	12	0	76	0	100	0	0	0	21	0	79	0
COM6	0	100	17	7	38	0	38	0	90	7	3	0	82	0	18	0
COM7	0	100	19	7	37	0	37	0	83	11	6	0	67	0	33	0
COM8	0	100	35	3	6	9	47	0	87	13	0	0	19	4	78	0
COM9	0	100	48	17	0	0	36	0	87	13	0	0	33	0	67	0
COM10	0	0	0	24	0	24	53	0	84	14	0	2	40	20	40	0
IND1	0	100	48	21	3	3	25	0	64	32	5	0	29	14	57	0
IND2	0	100	22	13	35	2	29	0	89	6	6	0	13	0	87	0
IND3	0	100	35	15	6	6	38	0	92	0	8	0	13	0	87	0
IND4	0	100	41	21	12	3	22	0	89	0	11	0	9	27	64	0
IND5	0	100	62	15	15	0	9	0	71	4	20	4	88	0	12	0
IND6	0	100	9	6	30	0	55	0	53	47	0	0	10	0	90	100
AGR1	100	0	14	10	67	0	10	0	100	0	0	0	0	7	93	0
REL1	100	0	26	0	6	0	68	0	75	25	0	0	30	0	70	0
GOV1	0	100	29	4	11	14	43	0	91	9	0	0	35	0	65	0
GOV2	100	0	0	0	0	100	0	0	100	0	0	0	19	0	81	0

Specific Occup. Class	W1	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML	MH
EDU1	100	0	18	0	9	9	64	0	84	16	0	0	29	0	71	0
EDU2	100	0	14	29	0	14	43	0	100	0	0	0	47	12	42	0

[1]*Refer to Table A-22 for states' classifications. For "Res1" Distribution, refer to Table A-18.*
[2] *Unreinforced SBTs URM, C3 and S5 are not allowed in West Coast Region where Design Levels are higher than Pre-Code.*

Table A-3. Distribution Percentage of Floor Area for Specific Building Types within each Building Occupancy Class, Low-Rise, Post-1970, West Coast (after ATC-13, 1985)[1][2]

Specific Occup. Class	W1	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML	MH
RES2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
RES3	100	0	0	0	40	60	0	0	75	13	0	13	100	0	0	100
RES4	100	0	38	0	25	38	0	24	76	0	0	0	91	9	0	0
RES5	100	0	25	25	0	50	0	17	83	0	0	0	88	12	0	0
RES6	100	0	25	25	0	50	0	0	50	0	50	0	100	0	0	0
COM1	0	100	69	8	15	8	0	16	27	3	41	14	88	13	0	0
COM2	0	100	33	8	25	33	0	3	21	0	71	5	86	14	0	0
COM3	0	100	30	20	20	30	0	7	32	0	49	12	94	6	0	0
COM4	0	100	33	22	11	33	0	13	50	0	27	10	92	8	0	0
COM5	0	100	33	22	11	33	0	13	50	0	27	10	92	8	0	0
COM6	0	100	40	7	7	47	0	17	54	0	29	0	93	7	0	0
COM7	0	100	76	0	0	24	0	33	50	0	17	0	100	0	0	0
COM8	0	100	66	23	3	9	0	9	68	0	18	5	82	18	0	0
COM9	0	100	57	43	0	0	0	0	75	0	25	0	84	16	0	0
COM10	0	0	36	36	0	27	0	4	72	0	4	19	70	30	0	0
IND1	0	100	37	54	6	4	0	4	38	0	46	13	92	8	0	100
IND2	0	100	42	29	19	10	0	0	19	0	76	6	100	0	0	0
IND3	0	100	45	30	15	9	0	0	26	0	60	15	100	0	0	0
IND4	0	100	49	34	9	8	0	3	37	3	40	17	94	6	0	0
IND5	0	100	48	32	8	12	0	0	18	0	69	13	94	6	0	100
IND6	0	100	19	29	52	0	0	0	27	0	53	20	100	0	0	100
AGR1	100	0	30	41	30	0	0	0	20	0	73	7	94	6	0	100
REL1	100	0	55	14	5	27	0	0	87	0	3	10	88	12	0	0
GOV1	0	100	52	14	10	24	0	5	84	0	0	11	64	36	0	0

Specific Occup. Class	W1	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML	MH
GOV2	100	0	9	21	0	70	0	0	59	0	0	41	30	70	0	0
EDU1	100	0	43	29	5	24	0	10	55	10	14	10	81	19	0	0
EDU2	100	0	40	40	0	20	0	0	80	0	20	0	89	11	0	0

[1]Refer to Table A-22 for states' classifications. For "Res1" Distribution, refer to Table A-19.
[2] Unreinforced SBTs URM, C3 and S5 are not allowed in West Coast Region where Design Levels are higher than Pre-Code.

Table A-4. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Mid-Rise, Pre-1950, West Coast (after ATC-13, 1985) [1][2]

Specific Occup. Class	S1M	S2M	S4M	S5M	C1M	C2M	C3M	PC2M	RM1M	RM2M	URMM
RES3	63	17	21	0	2	42	56	0	26	0	74
RES4	53	12	35	0	2	49	49	0	32	0	68
RES5	73	5	23	0	0	67	33	0	10	0	90
RES6	80	0	20	0	0	64	36	0	50	0	50
COM1	47	35	18	0	0	38	62	0	39	4	57
COM2	100	0	0	0	0	34	66	0	42	0	58
COM3	100	0	0	0	0	34	66	0	28	0	72
COM4	60	17	24	0	5	55	40	0	50	0	50
COM5	60	17	24	0	5	55	40	0	50	0	50
COM6	64	14	21	0	2	64	35	0	47	0	53
COM7	67	17	17	0	0	60	40	0	50	0	50
COM8	56	0	44	0	0	89	11	0	10	0	90
COM9	75	0	25	0	0	80	20	0	10	0	90
COM10	0	67	33	0	3	73	24	0	30	20	50
IND2	0	0	100	0	0	6	94	0	10	0	90
IND3	89	8	3	0	2	25	73	0	38	0	63
IND4	86	10	3	0	0	15	85	0	10	0	90
IND5	78	22	0	0	0	86	14	0	100	0	0
IND6	100	0	0	0	0	20	80	0	100	0	0
AGR1	100	0	0	0	0	25	75	0	100	0	0
REL1	100	0	0	0	0	10	90	0	100	0	0
GOV1	60	30	10	0	8	64	28	0	29	0	71
EDU2	33	0	67	0	0	95	5	0	71	0	29

[1] *Refer to Table A-22 for states' classifications.*
[2] *Unreinforced SBTs URM, C3 and S5 are not allowed in West Coast Region where Design Levels are higher than Pre-Code.*

Table A-5. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Mid-Rise, 1950-1970, West Coast (after ATC-13, 1985) [1][2]

Specific Occup. Class	S1M	S2M	S4M	S5M	C1M	C2M	C3M	PC2M	RM1M	RM2M	URMM
RES3	32	48	19	0	10	88	0	2	78	22	0
RES4	21	57	21	0	13	85	3	0	78	22	0
RES5	33	6	61	0	17	83	0	0	64	36	0
RES6	38	25	38	0	17	83	0	0	83	17	0
COM1	19	68	14	0	9	91	0	0	76	24	0
COM2	88	13	0	0	5	92	0	3	87	13	0
COM3	77	23	0	0	0	100	0	0	92	8	0
COM4	39	41	20	0	31	62	0	7	85	15	0
COM5	39	41	20	0	31	62	0	7	85	15	0
COM6	37	26	37	0	16	74	0	10	74	26	0
COM7	38	25	38	0	17	83	0	0	83	17	0
COM8	15	0	85	0	0	100	0	0	67	33	0
COM9	14	0	86	0	0	100	0	0	67	33	0
COM10	24	38	38	0	13	72	0	15	72	28	0
IND1	0	33	67	0	0	100	0	0	67	33	0
IND2	0	60	40	0	0	100	0	0	80	20	0
IND3	44	16	40	0	59	39	0	2	63	38	0
IND4	36	18	46	0	100	0	0	0	75	25	0
IND5	36	18	46	0	0	100	0	0	75	25	0
REL1	100	0	0	0	0	100	0	0	50	50	0
GOV1	42	17	42	0	27	68	0	5	78	22	0
GOV2	20	40	40	0	8	92	0	0	0	100	0
EDU2	57	0	43	0	13	88	0	0	60	40	0

[1] *Refer to Table A-22 for states' classifications.*
[2] *Unreinforced SBTs URM, C3 and S5 are not allowed in West Coast Region where Design Levels are higher than Pre-Code.*

Table A-6. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Mid-Rise, Post-1970, West Coast (after ATC-13, 1985) [1][2]

Specific Occup. Class	S1M	S2M	S4M	S5M	C1M	C2M	C3M	PC2M	RM1M	RM2M	URMM
RES3	23	58	20	0	22	62	0	16	80	20	0
RES4	31	54	15	0	34	56	0	9	81	19	0
RES5	30	33	37	0	30	63	0	7	69	31	0
RES6	50	20	30	0	22	78	0	0	100	0	0
COM1	74	20	7	0	35	50	0	15	75	25	0
COM2	54	46	0	0	45	30	0	24	50	50	0
COM3	35	55	10	0	26	44	0	31	57	43	0
COM4	63	17	20	0	33	56	0	11	64	36	0
COM5	63	17	20	0	33	56	0	11	64	36	0
COM6	51	18	31	0	23	75	0	2	86	14	0
COM7	50	20	30	0	22	78	0	0	100	0	0
COM8	0	100	0	0	100	0	0	0	100	0	0
COM9	0	100	0	0	100	0	0	0	100	0	0
COM10	27	53	20	0	5	85	0	10	86	14	0
IND3	91	7	1	0	82	14	0	4	75	25	0
IND4	100	0	0	0	100	0	0	0	100	0	0
IND5	51	40	9	0	65	25	0	10	77	23	0
REL1	0	100	0	0	100	0	0	0	0	100	0
GOV1	49	22	29	0	58	32	0	11	82	18	0
GOV2	31	25	44	0	0	100	0	0	0	0	0
EDU2	57	14	29	0	50	50	0	0	67	33	0

[1]Refer to Table A-22 for states' classifications.
[2] Unreinforced SBTs URM, C3 and S5 are not allowed in West Coast Region where Design Levels are higher than Pre-Code.

Table A-7. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, High-Rise, Pre-1950, West Coast (after ATC-13, 1985) [1][2]

Specific Occup. Class	S1H	S2H	S4H	S5H	C1H	C2H	C3H	PC2H	RM2H
RES3	93	2	5	0	14	41	40	5	100
RES4	88	6	6	0	16	41	37	6	100
RES5	50	17	33	0	0	43	57	0	100
COM4	77	16	7	0	3	54	41	3	100
COM5	77	16	7	0	3	54	41	3	100
COM6	85	14	2	0	3	71	24	3	100
GOV1	84	8	8	0	8	81	8	3	100
EDU2	11	11	78	0	0	73	27	0	100

[1]*Refer to Table A-22 for states' classifications.*
[2] *Unreinforced SBTs URM, C3 and S5 are not allowed in West Coast Region where Design Levels are higher than Pre-Code.*

Table A-8. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, High-Rise, 1950-1970, West Coast (after ATC-13, 1985) [1][2]

Specific Occup. Class	S1H	S2H	S4H	S5H	C1H	C2H	C3H	PC2H	RM2H
RES3	53	37	11	0	33	60	0	8	100
RES4	72	15	13	0	38	59	0	3	100
RES5	33	25	42	0	86	14	0	0	100
COM4	48	31	21	0	43	50	0	7	100
COM5	48	31	21	0	43	50	0	7	100
COM6	44	34	22	0	20	75	0	5	100
GOV1	57	16	27	0	56	44	0	0	100
EDU2	47	27	27	0	100	0	0	0	100

[1]*Refer to Table A-22 for states' classifications.*
[2] *Unreinforced SBTs URM, C3 and S5 are not allowed in West Coast Region where Design Levels are higher than Pre-Code.*

Table A-9. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, High-Rise, Post-1970, West Coast (after ATC-13, 1985) [1][2]

Specific Occup. Class	S1H	S2H	S4H	S5H	C1H	C2H	C3H	PC2H	RM2H
RES3	80	11	9	0	42	47	0	12	100
RES4	78	14	8	0	59	33	0	7	100
RES5	40	29	32	0	100	0	0	0	100
COM4	70	13	18	0	70	25	0	5	100
COM5	68	13	19	0	71	24	0	5	100
COM6	64	9	27	0	43	57	0	0	100
GOV1	65	18	18	0	70	30	0	0	100
EDU2	60	20	20	0	100	0	0	0	100

[1]Refer to Table A-22 for states' classifications.
[2] Unreinforced SBTs URM, C3 and S5 are not allowed in West Coast Region where Design Levels are higher than Pre-Code.

Table A-10. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Low-Rise, Mid-West[1]

Specific Occup. Class	W1	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML	MH
RES2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
RES3	100	0	7	13	37	20	23	9	29	4	49	9	8	0	92	0
RES4	100	0	7	13	37	20	23	9	29	4	49	9	6	4	90	0
RES5	100	0	7	13	37	20	23	9	29	4	49	9	6	0	94	0
RES6	100	0	7	13	37	20	23	9	29	4	49	9	10	0	90	0
COM1	0	100	7	13	37	20	23	0	50	0	50	0	7	0	93	0
COM2	0	100	7	13	37	20	23	7	33	7	47	7	7	0	93	0
COM3	0	100	7	13	37	20	23	0	50	0	50	0	7	0	93	0
COM4	0	100	7	13	37	20	23	0	50	0	50	0	7	0	93	0
COM5	0	100	7	13	37	20	23	0	50	0	50	0	7	0	93	0
COM6	0	100	0	20	40	20	20	9	30	6	47	9	10	0	90	0
COM7	0	100	7	13	37	20	23	0	50	0	50	0	7	0	93	0
COM8	0	100	7	13	37	20	23	0	50	0	50	0	7	0	93	0
COM9	0	100	5	15	35	20	25	9	29	4	49	9	10	0	90	0
COM10	0	100	7	13	37	20	23	9	30	6	47	9	10	0	90	0
IND1	0	100	7	14	36	19	24	8	28	8	48	8	10	0	90	0
IND2	0	100	7	13	37	20	23	7	33	7	47	7	10	0	90	0
IND3	0	100	7	13	37	20	23	7	33	7	47	7	10	0	90	0
IND4	0	100	7	14	36	19	24	8	28	8	48	8	10	0	90	0
IND5	0	100	7	13	37	20	23	7	33	7	47	7	7	0	93	0
IND6	0	100	7	13	37	20	23	0	50	0	50	0	7	0	93	0
AGR1	0	100	7	13	37	20	23	7	33	7	47	7	7	0	93	0
REL1	100	0	0	20	33	20	27	0	50	0	50	0	4	4	91	0
GOV1	0	100	40	60	0	0	0	41	35	0	24	0	9	0	91	0
GOV2	0	100	29	71	0	0	0	25	75	0	0	0	0	7	93	0
EDU1	0	100	29	71	0	0	0	42	58	0	0	0	18	0	82	0

Specific Occup. Class	W1	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML	MH
EDU2	0	100	30	60	0	0	10	42	58	0	0	0	0	21	79	0

[1]Refer to Table A-22 for states' classifications. For "Res1" Distribution, refer to Table A-20.
[2] Unreinforced SBTs URM, C3 and S5 are not allowed in Mid-West Region where Design Levels are higher than Low-Code.

Table A-11. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Mid-Rise, Mid-West[1] [2]

Specific Occup. Class	S1M	S2M	S4M	S5M	C1M	C2M	C3M	PC2M	RM1M	RM2M	URMM
RES3	0	50	35	15	23	65	0	12	0	10	90
RES4	0	50	35	15	23	62	3	12	0	10	90
RES5	0	50	35	15	25	62	2	11	0	10	90
COM1	7	44	36	13	24	60	4	11	0	20	80
COM2	0	70	30	0	23	62	3	12	0	10	90
COM3	7	44	36	13	24	60	4	11	0	20	80
COM4	7	44	36	13	24	60	4	11	0	20	80
COM5	7	44	36	13	24	60	4	11	0	20	80
COM6	7	44	36	13	24	60	4	12	0	20	80
COM7	7	44	36	13	24	60	4	11	0	20	80
COM8	7	44	36	13	24	60	4	11	0	20	80
COM10	7	47	33	13	24	61	3	11	0	20	80
IND2	0	70	30	0	23	62	3	12	0	10	90
IND3	0	70	30	0	23	62	3	12	0	10	90
IND5	0	70	30	0	23	62	3	12	0	10	90
AGR1	0	70	30	0	23	62	3	12	0	10	90
REL1	7	44	36	13	24	60	4	11	0	20	80
GOV1	45	55	0	0	55	45	0	0	0	14	86
EDU2	33	67	0	0	41	59	0	0	0	23	77

[1]Refer to Table A-22 for states' classifications.
[2] Unreinforced SBTs URM, C3 and S5 are not allowed in Mid-West Region where Design Levels are higher than Low-Code.

Table A-12. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, High-Rise, Mid-West[1] [2]

Specific Occup. Class	S1H	S2H	S4H	S5H	C1H	C2H	C3H	PC2H	RM2H
RES3	15	65	20	0	22	59	9	9	100
RES4	15	65	20	0	22	59	9	9	100
RES5	15	65	20	0	26	74	0	0	100
COM4	16	64	20	0	23	62	8	8	100
COM5	16	64	20	0	23	62	8	8	100
COM6	16	64	20	0	25	68	4	4	100
COM7	16	64	20	0	23	62	8	8	100
COM10	17	63	20	0	26	74	0	0	100
AGR1	20	60	20	0	20	54	13	13	100

[1] *Refer to Table A-22 for states' classifications.*

[2] *Unreinforced SBTs URM, C3 and S5 are not allowed in Mid-West Region where Design Levels are higher than Low-Code.*

Table A-13. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Low-Rise, East Coast[1] [2]

Specific Occup. Class	W1	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML	MH
RES2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
RES3	100	0	0	100	0	0	0	50	50	0	0	0	16	13	71	0
RES4	100	0	38	31	0	0	31	44	22	0	17	17	14	14	71	0
RES5	100	0	37	32	0	0	32	43	15	8	20	15	15	15	71	0
RES6	100	0	41	30	0	0	30	40	15	10	20	15	16	13	71	0
COM1	0	100	36	27	9	0	29	43	29	0	29	0	17	9	74	0
COM2	0	100	36	25	12	0	27	43	29	0	29	0	13	17	71	0
COM3	0	100	25	18	39	0	18	43	29	0	29	0	15	10	75	0
COM4	0	100	34	25	13	0	28	44	22	0	33	0	15	12	73	0
COM5	0	100	29	20	29	0	22	42	25	0	17	17	17	10	73	0
COM6	0	100	40	27	0	0	33	40	16	8	20	16	17	11	72	0
COM7	0	100	25	18	38	0	20	38	25	0	38	0	14	14	71	0
COM8	0	100	36	25	11	0	28	43	29	0	29	0	14	14	71	0
COM9	0	100	32	21	19	3	25	47	13	0	20	20	18	12	71	0
COM10	0	100	40	28	0	0	32	41	15	8	19	16	10	0	90	0
IND1	0	100	37	25	7	3	28	44	19	0	19	19	16	16	68	0
IND2	0	100	30	18	30	0	22	42	25	0	17	17	14	18	68	0
IND3	0	100	38	28	5	0	29	40	20	0	20	20	17	11	72	0
IND4	0	100	38	28	4	0	29	43	29	0	29	0	11	17	72	0
IND5	0	100	37	25	4	3	30	44	19	0	19	19	0	17	83	0
IND6	0	100	35	23	12	3	27	45	18	0	18	18	11	16	74	0
AGR1	0	100	24	18	36	0	21	100	0	0	0	0	18	12	71	0
REL1	100	0	36	36	0	0	27	33	33	0	33	0	15	13	72	0
GOV1	0	100	39	26	5	0	31	45	27	0	18	9	16	16	68	0
GOV2	0	100	36	25	9	0	30	40	15	10	20	15	14	18	68	0

Specific Occup. Class	W1	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML	MH
EDU1	0	100	40	30	0	0	30	42	25	0	17	17	16	16	69	0
EDU2	0	100	40	29	0	0	31	40	15	10	20	15	16	13	71	0

[1]Refer to Table A-22 for states' classifications. For "RES1" Distribution, refer to Table A-21.
[2] Unreinforced SBTs URM, C3 and S5 are not allowed in East Coast Region where Design Levels are higher than Low-Code.

Table A-14. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Mid-Rise, East Coast[1] [2]

Specific Occup. Class	S1M	S2M	S4M	S5M	C1M	C2M	C3M	PC2M	RM1M	RM2M	URMM
RES3	43	57	0	0	26	13	0	61	0	19	81
RES4	38	50	0	13	45	23	5	28	0	19	81
RES5	35	50	0	15	47	22	6	24	0	16	84
COM1	37	47	3	13	38	23	0	38	0	20	80
COM2	36	47	5	13	33	25	0	42	0	21	79
COM3	38	50	0	12	25	20	0	55	0	19	81
COM4	35	48	5	13	35	20	0	45	0	18	83
COM5	34	48	5	14	38	24	0	38	0	17	83
COM6	36	47	3	14	44	22	7	26	0	13	87
COM7	36	48	5	12	35	20	0	45	0	16	84
COM8	35	48	5	13	38	23	0	38	0	21	79
COM10	38	50	0	12	53	24	8	15	0	10	90
IND2	37	47	3	13	43	22	9	26	0	18	82
IND3	36	46	4	13	43	29	0	29	0	18	82
IND5	35	47	4	13	45	30	0	25	0	17	83
AGR1	36	47	4	13	31	15	0	54	0	18	82
REL1	31	56	0	13	21	16	0	63	0	18	82
GOV1	36	45	5	14	41	29	0	29	0	18	82
EDU2	35	48	4	13	40	20	8	32	0	15	85

[1] *Refer to Table A-22 for states' classifications.*
[2] *Unreinforced SBTs URM, C3 and S5 are not allowed in East Coast Region where Design Levels are higher than Low-Code.*

Table A-15. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, High-Rise, East Coast[1] [2]

Specific Occup. Class	S1H	S2H	S4H	S5H	C1H	C2H	C3H	PC2H	RM2H
RES3	22	57	22	0	59	29	3	9	100
RES4	22	57	22	0	59	29	3	9	100
RES5	21	57	21	0	59	29	4	7	100
COM4	23	55	23	0	60	32	0	8	100
COM5	23	55	23	0	60	32	0	8	100
COM6	22	56	22	0	59	28	7	7	100
COM7	22	56	22	0	58	33	0	8	100
COM10	23	55	23	0	58	28	5	8	100
AGR1	24	14	62	0	32	68	0	0	100

[1]Refer to Table A-22 for states' classifications.
[2] Unreinforced SBTs URM, C3 and S5 are not allowed in East Coast Region where Design Levels are higher than Low-Code.

Table A-16. Distribution Percentage of Floor Area for Specific Building Types within “RES1” Building Occupancy Class, Pre-1950, West Coast[1] [2]

Specific Occup. Class	S1H	S2H	S4H	S5H	C1H	C2H	C3H	PC2H	RM2H
RES3	22	57	22	0	59	29	3	9	100
RES4	22	57	22	0	59	29	3	9	100
RES5	21	57	21	0	59	29	4	7	100
COM4	23	55	23	0	60	32	0	8	100
COM5	23	55	23	0	60	32	0	8	100
COM6	22	56	22	0	59	28	7	7	100
COM7	22	56	22	0	58	33	0	8	100
COM10	23	55	23	0	58	28	5	8	100
AGR1	24	14	62	0	32	68	0	0	100

[1]State FIPS are two digit unique number representative of each state and U.S. territory. Refer to Table A-22 for a complete list of State FIPS.
[2] Unreinforced SBTs URM, C3 and S5 are not allowed in West Coast Region where Design Levels are higher than Pre-Code.

Table A-17. Distribution Percentage of Floor Area for Specific Building Types within "RES1" Building Occupancy Class, 1950-1970, West Coast[1]

State FIPS	State Abbreviation	State	W1	C2L	RM1L	URML
02	AK	Alaska	100	100	100	0
04	AZ	Arizona	100	100	90	10
06	CA	California	100	100	100	0
08	CO	Colorado	100	100	88	13
15	HI	Hawaii	100	100	86	14
16	ID	Idaho	100	100	80	20
30	MT	Montana	100	100	100	0
35	NM	New Mexico	100	100	88	12
32	NV	Nevada	100	100	100	0
41	OR	Oregon	100	100	100	0
49	UT	Utah	100	100	89	11
53	WA	Washington	100	100	100	0
56	WY	Wyoming	100	100	88	13

[1] Unreinforced SBTs URM, C3 and S5 are not allowed in West Coast Region where Design Levels are higher than Pre-Code.

Table A-18. Distribution Percentage of Floor Area for Specific Building Types within "RES1" Building Occupancy Class, Post-1970, West Coast [1]

State FIPS	State Abbreviation	State	W1	C2L	RM1L	URML
02	AK	Alaska	100	100	100	0
04	AZ	Arizona	100	100	100	0
60	AS	American Samoa	100	100	100	0
06	CA	California	100	100	100	0
08	CO	Colorado	100	100	100	0
66	GU	Guam	100	100	100	0
15	HI	Hawaii	100	100	100	0
16	ID	Idaho	100	100	100	0
69	MP	Northern Mariana Islands	100	100	100	0
30	MT	Montana	100	100	100	0
35	NM	New Mexico	100	100	100	0
32	NV	Nevada	100	100	100	0
41	OR	Oregon	100	100	100	0
49	UT	Utah	100	100	100	0
53	WA	Washington	100	100	100	0
56	WY	Wyoming	100	100	100	0

[1] *Unreinforced SBTs URM, C3 and S5 are not allowed in West Coast Region where Design Levels are higher than Pre-Code.*

Table A-19. Distribution Percentage of Floor Area for Specific Building Types within "RES1" Building Occupancy Class, Mid-West [1]

State FIPS	State Abbreviation	State	Specific Building Type W1	Specific Building Type C2L	Specific Building Type URML
05	AR	Arkansas	100	100	100
19	IA	Iowa	100	100	100
17	IL	Illinois	100	100	100
18	IN	Indiana	100	100	100
20	KS	Kansas	100	100	100
21	KY	Kentucky	100	100	100
22	LA	Louisiana	100	100	100
26	MI	Michigan	100	100	100
27	MN	Minnesota	100	100	100
29	MO	Missouri	100	100	100
28	MS	Mississippi	100	100	100
38	ND	North Dakota	100	100	100
31	NE	Nebraska	100	100	100
39	OH	Ohio	100	100	100
40	OK	Oklahoma	100	100	100
46	SD	South Dakota	100	100	100
47	TN	Tennessee	100	100	100
48	TX	Texas	100	100	100
55	WI	Wisconsin	100	100	100

[1] *Unreinforced SBTs URM, C3 and S5 are not allowed in Mid-West Region where Design Levels are higher than Low-Code.*

Table A-20. Distribution Percentage of Floor Area for Specific Building Types within "RES1" Building Occupancy Class, East Coast [1]

State FIPS	State Abbreviation	State	Specific Building Type W1	Specific Building Type C2L	Specific Building Type URML
01	AL	Alabama	100	100	100
09	CT	Connecticut	100	100	100
11	DC	District of Columbia	100	100	100
10	DE	Delaware	100	100	100
12	FL	Florida	100	100	100
13	GA	Georgia	100	100	100
25	MA	Massachusetts	100	100	100
24	MD	Maryland	100	100	100
23	ME	Maine	100	100	100
37	NC	North Carolina	100	100	100
33	NH	New Hampshire	100	100	100
34	NJ	New Jersey	100	100	100
36	NY	New York	100	100	100
42	PA	Pennsylvania	100	100	100
72	PR	Puerto Rico	100	100	100
44	RI	Rhode Island	100	100	100
45	SC	South Carolina	100	100	100
51	VA	Virginia	100	100	100
50	VT	Vermont	100	100	100
78	VI	U.S. Virgin Islands	100	100	100
54	WV	West Virginia	100	100	100

[1] *Unreinforced SBTs URM, C3 and S5 are not allowed in East Coast Region where Design Levels are higher than Low-Code.*

Table A-21. Regional Distribution of States/Territories

State/Territory FIPS	State/Territory Abbreviation	State/Territory Name	Regional Group
02	AK	Alaska	West Coast
01	AL	Alabama	East Coast
05	AR	Arkansas	Mid-West
04	AZ	Arizona	West Coast
06	CA	California	West Coast
08	CO	Colorado	West Coast
09	CT	Connecticut	East Coast
11	DC	District of Columbia	East Coast
10	DE	Delaware	East Coast
12	FL	Florida	East Coast
13	GA	Georgia	East Coast
15	HI	Hawaii	West Coast
19	IA	Iowa	Mid-West
16	ID	Idaho	West Coast
17	IL	Illinois	Mid-West
18	IN	Indiana	Mid-West
20	KS	Kansas	Mid-West
21	KY	Kentucky	Mid-West
22	LA	Louisiana	Mid-West
25	MA	Massachusetts	East Coast
24	MD	Maryland	East Coast
23	ME	Maine	East Coast
26	MI	Michigan	Mid-West
27	MN	Minnesota	Mid-West
29	MO	Missouri	Mid-West
28	MS	Mississippi	Mid-West

State/Territory FIPS	State/Territory Abbreviation	State/Territory Name	Regional Group
30	MT	Montana	West Coast
37	NC	North Carolina	East Coast
38	ND	North Dakota	Mid-West
31	NE	Nebraska	Mid-West
33	NH	New Hampshire	East Coast
34	NJ	New Jersey	East Coast
35	NM	New Mexico	West Coast
32	NV	Nevada	West Coast
36	NY	New York	East Coast
39	OH	Ohio	Mid-West
40	OK	Oklahoma	Mid-West
41	OR	Oregon	West Coast
42	PA	Pennsylvania	East Coast
44	RI	Rhode Island	East Coast
45	SC	South Carolina	East Coast
46	SD	South Dakota	Mid-West
47	TN	Tennessee	Mid-West
48	TX	Texas	Mid-West
49	UT	Utah	West Coast
51	VA	Virginia	East Coast
50	VT	Vermont	East Coast
53	WA	Washington	West Coast
55	WI	Wisconsin	Mid-West
54	WV	West Virginia	East Coast
56	WY	Wyoming	West Coast
60	AS	American Samoa	West Coast
66	GU	Guam	West Coast

State/Territory FIPS	State/Territory Abbreviation	State/Territory Name	Regional Group
69	MP	Northern Mariana Islands	West Coast
72	PR	Puerto Rico	East Coast
78	VI	U.S. Virgin Islands	East Coast

Appendix B. Earthquake Essential Facilities Mapping Schemes

Essential Facility data for occupancy types COM6, EDU1 and GOV2 in the general building stock were updated for Hazus 6.1. However, the site-specific building type and design level assignments for the site-specific Essential Facility data have not been updated following the updated 6.1 approach.

Table B-1 Benchmark Years for Design Level Assignment

Building Scheme Seismic Design Level (Scheme Name[1])	Pre-Code	Low Code	Moderate Code	Moderate Superior	High Code	High Superior
High (XX3)	< 1940	1940	1960	N/A	1973	2000
Moderate (XX2)	< 1940	1940	1973	2000	N/A	N/A
Low (XX1)	< 1973	1973	2000	N/A	N/A	N/A

[1](XX#) is the general mapping scheme designation stored in field = BldgSchemesId in SQL table hzTract. XX is the two letter State designation (e.g., CA1, CA2 and CA3), and the following number designates the seismic design level upon which the mapping scheme is based.

Table B-2 Example Design Level Assignments Using Benchmark Years

Year Built	High Seismic Design Level (Scheme XX3[1])	Moderate Seismic Design Level (Scheme XX2[1])	Low Seismic Design Level (Scheme XX1[1])
1912	PC	PC	PC
1940	LC	LC	PC
1972	MC	LC	PC
1973	HC	MC	LC
2010	HS	MS	MC

[1](XX#) is the general mapping scheme designation stored in field = BldgSchemesId in SQL table hzTract. XX is the two letter State designation (e.g., CA1, CA2 and CA3), and the following number designates the seismic design level upon which the mapping scheme is based.

Table B-3 State Assignment of East or West for Model Building Type Assignment

Area	State List
East	AL, AR, CT, DE, DC, FL, GA, IL, IN, IA, KS, KY, LA, ME, MD, MA, MI, MN, MS, MO, NE, NH, NJ, NY, NC, ND, OH, OK, PA, RI, SC, SD, TN, TX, VT, VA, WV, WI, PR
West	AK, AZ, CA, CO, HI, ID, MT, NV, NM, OR, UT, WA, WY, AS (TS only), GU (TS Only), MP (TS Only), VI (TS Only)

Table B-4 Essential Facility Model Building Type Assignment

Design Level	Urban Area	Area	Model Building Type Assignment for: eqCareFlty, eqSchool	Model Building Type Assignment for: eqFireStation, eqPoliceStation, eqEmergencyCtr
MC, HC, or HS	Rural	West	W2	W1
MC, HC, or HS	Rural	East	RM1L	RM1L
MC, HC, or HS	Urban	West	RM1L	RM1L
MC, HC, or HS	Urban	East	RM1L	RM1L
PC or LC	Rural	West	W2	W1
PC or LC	Rural	East	URML	URML
PC or LC	Urban	West	URML	URML
PC or LC	Urban	East	URML	URML

Appendix C. Seismic Design Level Assignment Matrices for States included in *Building Codes Save: A Nationwide Study* (FEMA, 2020)

Table C-1 IBC Era Seismic Design Level Matrix: Alaska

Construction Year	1995 through 1998	1999 through 2023 (residential)	1999 through 2001 (non residential)	2002 through 2005 (non residential)	2006 through 2007 (non residential)	2008 through 2012 (non residential)	2013 through 2017 (non residential)	2018 through 2023 (non residential)
RES1, RES3A <=2,000 sqft (use 2,000 for Alaska)	1994 UBC Design Level for W1 > 2,000 sf	1997 UBC W1/RES1 Design Level, <=2000 SQFT						
RES1, RES3A >2,000 sqft (use 2,000 for Alaska)	1994 UBC Design Level for W1 <= 2,000 sf	1997 UBC W1/RES1 Design Level, > 2000 SQFT						
Low-Rise Design Level	1994 UBC Design Level for Non-W1		1997 UBC Low-Rise Design Level	IBC 2000 Low-Rise Design Level	IBC 2003, Low-Rise Design Level	IBC 2006, Low-Rise Design Level	IBC 2009, Low-Rise Design Level	IBC 2012, Low-Rise Design Level
Mid-Rise/High-Rise Design Level	1994 UBC Design Level for Non-W1		1997 UBC Mid-Rise/High-Rise Design Level	IBC 2000 Mid-Rise/High-Rise Design Level	IBC 2003, Mid-Rise/High-Rise Design Level	IBC 2006, Mid-Rise/High-Rise Design Level	IBC 2009, Mid-Rise/High-Rise Design Level	IBC 2012, Low-Rise Design Level

Note: Essential Facilities (COM6, GOV2, and EDU1) if not Severe design level should be assigned Special design level (update HC to HS, MC to MS, and LC to LS) to prevent any increase in vulnerability.

Table C-2 IBC Era Seismic Design Level Matrix: City of Fairbanks and North Pole, Alaska

Construction Year	1999 through 2002	2003 through 2005	2006 through 2008	2009 through 2011	2012 through 2016	2017 through 2023
RES1, RES3A <=2,000 sqft (use 2,000 for Alaska)	1997 UBC W1/RES1 Design Level, <=2000 SQFT	IRC 2000 W1/RES1 Design Level, <=2000 SQFT	IRC 2003 W1/RES1 Design Level, <=2000 SQFT	IRC 2006 W1/RES1 Design Level, <=2000 SQFT	IRC 2009 W1/RES1 Design Level, <=2000 SQFT	IRC 2015 W1/RES1 Design Level, <=2000 SQFT
RES1, RES3A >2,000 sqft (use 2,000 for Alaska)	1997 UBC W1/RES1 Design Level, > 2000 SQFT	IRC 2000 W1/RES1 Design Level, > 2000 SQFT	IRC 2003 W1/RES1 Design Level, > 2000 SQFT	IRC 2006 W1/RES1 Design Level, > 2000 SQFT	IRC 2009 W1/RES1 Design Level, > 2000 SQFT	IRC 2015 W1/RES1 Design Level, > 2000 SQFT
Low-Rise Design Level	1997 UBC Low-Rise Design Level	IBC 2000 Low-Rise Design Level	IBC 2003, Low-Rise Design Level	IBC 2006, Low-Rise Design Level	IBC 2009, Low-Rise Design Level	IBC 2015, Low-Rise Design Level
Mid-Rise/High-Rise Design Level	1997 UBC Mid-Rise/High-Rise Design Level	IBC 2000 Mid-Rise/High-Rise Design Level	IBC 2003, Mid-Rise/High-Rise Design Level	IBC 2006, Mid-Rise/High-Rise Design Level	IBC 2009, Mid-Rise/High-Rise Design Level	IBC 2015, Mid-Rise/High-Rise Design Level

Note: Essential Facilities (COM6, GOV2, and EDU1) if not Severe design level should be assigned Special design level (update HC to HS, MC to MS, and LC to LS) to prevent any increase in vulnerability.

Table C-3 IBC Era Seismic Design Level Matrix: City of Kenai, Seward and Soldotna, Alaska

Construction Year	1999 through 2003	2004 through 2005	2006 through 2008	2009 through 2013	2014 through 2016	2014 through 2018	2017 through 2023	2019 through 2023
RES1, RES3A <=2,000 sqft (use 2,000 for Alaska)	1997 UBC W1/RES1 Design Level, <=2000 SQFT	IRC 2000 W1/RES1 Design Level, <=2000 SQFT	IRC 2003 W1/RES1 Design Level, <=2000 SQFT	IRC 2006 W1/RES1 Design Level, <=2000 SQFT	IRC 2009 W1/RES1 Design Level, <=2000 SQFT		IRC 2012 W1/RES1 Design Level, <=2000 SQFT	
RES1, RES3A >2,000 sqft (use 2,000 for Alaska)	1997 UBC W1/RES1 Design Level, > 2000 SQFT	IRC 2000 W1/RES1 Design Level, > 2000 SQFT	IRC 2003 W1/RES1 Design Level, > 2000 SQFT	IRC 2006 W1/RES1 Design Level, > 2000 SQFT	IRC 2009 W1/RES1 Design Level, > 2000 SQFT		IRC 2012 W1/RES1 Design Level, > 2000 SQFT	
Low-Rise Design Level	1997 UBC Low-Rise Design Level	IBC 2000 Low-Rise Design Level	IBC 2003, Low-Rise Design Level	IBC 2006, Low-Rise Design Level		IBC 2009, Low-Rise Design Level		IBC 2012, Low-Rise Design Level
Mid-Rise/High-Rise Design Level	1997 UBC Mid-Rise/High-Rise Design Level	IBC 2000 Mid-Rise/High-Rise Design Level	IBC 2003, Mid-Rise/High-Rise Design Level	IBC 2006, Mid-Rise/High-Rise Design Level		IBC 2009, Mid-Rise/High-Rise Design Level		IBC 2012, Mid-Rise/High-Rise Design Level

Note: Essential Facilities (COM6, GOV2, and EDU1) if not Severe design level should be assigned Special design level (update HC to HS, MC to MS, and LC to LS) to prevent any increase in vulnerability.

Table C-4 IBC Era Seismic Design Level Matrix: City of Ketchikan, Alaska

Construction Year	1999 through 2000	2001 through 2005	2006 through 2010	2011 through 2013	2014 through 2023
RES1, RES3A <=2,000 sqft (use 2,000 for Alaska)	1994 UBC Design Level for W1 > 2,000 sf	1997 UBC W1/RES1 Design Level, <=2000 SQFT	IRC 2003 W1/RES1 Design Level, <=2000 SQFT	IRC 2006 W1/RES1 Design Level, <=2000 SQFT	IRC 2012 W1/RES1 Design Level, <=2000 SQFT
RES1, RES3A >2,000 sqft	1994 UBC Design Level for W1 <= 2,000 sf	1997 UBC W1/RES1 Design Level, > 2000 SQFT	IRC 2003 W1/RES1 Design Level, > 2000 SQFT	IRC 2006 W1/RES1 Design Level, > 2000 SQFT	IRC 2012 W1/RES1 Design Level, > 2000 SQFT
Low-Rise Design Level	1994 UBC Design Level for Non-W1	1997 UBC Low-Rise Design Level	IBC 2003, Low-Rise Design Level	IBC 2006, Low-Rise Design Level	IBC 2012, Low-Rise Design Level
Mid-Rise/High-Rise Design Level	1994 UBC Design Level for Non-W1	1997 UBC Mid-Rise/High-Rise Design Level	IBC 2003, Mid-Rise/High-Rise Design Level	IBC 2006, Mid-Rise/High-Rise Design Level	IBC 2012, Mid-Rise/High-Rise Design Level

Note: Essential Facilities (COM6, GOV2, and EDU1) if not Severe design level should be assigned Special design level (update HC to HS, MC to MS, and LC to LS) to prevent any increase in vulnerability.

Table C-5 IBC Era Seismic Design Level Matrix: City of Palmer, Alaska

Construction Year	1999 through 2006	2007 through 2008	2009 through 2011	2012 through 2017	2018 through 2023
RES1, RES3A <=2,000 sqft	1997 UBC W1/RES1 Design Level, <=2000 SQFT	IRC 2003 W1/RES1 Design Level, <=2000 SQFT	IRC 2006 W1/RES1 Design Level, <=2000 SQFT	IRC 2009 W1/RES1 Design Level, <=2000 SQFT	IRC 2015 W1/RES1 Design Level, <=2000 SQFT
RES1, RES3A >2,000 sqft	1997 UBC W1/RES1 Design Level, > 2000 SQFT	IRC 2003 W1/RES1 Design Level, > 2000 SQFT	IRC 2006 W1/RES1 Design Level, > 2000 SQFT	IRC 2009 W1/RES1 Design Level, > 2000 SQFT	IRC 2015 W1/RES1 Design Level, > 2000 SQFT
Low-Rise Design Level	1997 UBC Low-Rise Design Level	IBC 2003, Low-Rise Design Level	IBC 2006, Low-Rise Design Level	IBC 2009, Low-Rise Design Level	IBC 2015, Low-Rise Design Level
Mid-Rise/High-Rise Design Level	1997 UBC Mid-Rise/High-Rise Design Level	IBC 2003, Mid-Rise/High-Rise Design Level	IBC 2006, Mid-Rise/High-Rise Design Level	IBC 2009, Mid-Rise/High-Rise Design Level	IBC 2015, Mid-Rise/High-Rise Design Level

Note: Essential Facilities (COM6, GOV2, and EDU1) if not Severe design level should be assigned Special design level (update HC to HS, MC to MS, and LC to LS) to prevent any increase in vulnerability.

Table C-6 IBC Era Seismic Design Level Matrix: City of Anchorage within the Building Safety Service Area (BSSA), Alaska

Construction Year	1999 through 2003	2004 through 2005	2006 through 2008	2009 through 2011	2012 through 2016	2017 through 2023
RES1, RES3A <=2,000 sqft	1997 UBC W1/RES1 Design Level, <=2000 SQFT	IRC 2000 W1/RES1 Design Level, <=2000 SQFT	IRC 2003 W1/RES1 Design Level, <=2000 SQFT	IRC 2006 W1/RES1 Design Level, <=2000 SQFT	IRC 2009 W1/RES1 Design Level, <=2000 SQFT	IRC 2012 W1/RES1 Design Level, <=2000 SQFT
RES1, RES3A >2,000 sqft	1997 UBC W1/RES1 Design Level, > 2000 SQFT	IRC 2000 W1/RES1 Design Level, > 2000 SQFT	IRC 2003 W1/RES1 Design Level, > 2000 SQFT	IRC 2006 W1/RES1 Design Level, > 2000 SQFT	IRC 2009 W1/RES1 Design Level, > 2000 SQFT	IRC 2012 W1/RES1 Design Level, > 2000 SQFT
Low-Rise Design Level	1997 UBC Low-Rise Design Level	IBC 2000 Low-Rise Design Level	IBC 2003, Low-Rise Design Level	IBC 2006, Low-Rise Design Level	IBC 2009, Low-Rise Design Level	IBC 2012, Low-Rise Design Level
Mid-Rise/High-Rise Design Level	1997 UBC Mid-Rise/High-Rise Design Level	IBC 2000 Mid-Rise/High-Rise Design Level	IBC 2003, Mid-Rise/High-Rise Design Level	IBC 2006, Mid-Rise/High-Rise Design Level	IBC 2009, Mid-Rise/High-Rise Design Level	IBC 2012, Mid-Rise/High-Rise Design Level

Note: Essential Facilities (COM6, GOV2, and EDU1) if not Severe design level should be assigned Special design level (update HC to HS, MC to MS, and LC to LS) to prevent any increase in vulnerability.

Table C-7 IBC Era Seismic Design Level Matrix: City of Juneau, Alaska

Construction Year	1999 through 2004	2005 through 2009	2010 through 2014	2015 through 2017	2018 through 2023
RES1, RES3A <=2,000 sqft	1994 UBC W1/RES1 Design Level, <=2000 SQFT	IRC 2003 W1/RES1 Design Level, <=2000 SQFT	IRC 2006 W1/RES1 Design Level, <=2000 SQFT	IRC 2009 W1/RES1 Design Level, <=2000 SQFT	IRC 2012 W1/RES1 Design Level, <=2000 SQFT
RES1, RES3A >2,000 sqft	1994 UBC W1/RES1 Design Level, > 2000 SQFT	IRC 2003 W1/RES1 Design Level, > 2000 SQFT	IRC 2006 W1/RES1 Design Level, > 2000 SQFT	IRC 2009 W1/RES1 Design Level, > 2000 SQFT	IRC 2012 W1/RES1 Design Level, <=2000 SQFT
Low-Rise Design Level	1994 UBC Low-Rise Design Level	IBC 2003, Low-Rise Design Level	IBC 2006, Low-Rise Design Level	IBC 2009, Low-Rise Design Level	IRC 2012 W1/RES1 Design Level, <=2000 SQFT
Mid-Rise/High-Rise Design Level	1994 UBC Mid-Rise/High-Rise Design Level	IBC 2003, Mid-Rise/High-Rise Design Level	IBC 2006, Mid-Rise/High-Rise Design Level	IBC 2009, Mid-Rise/High-Rise Design Level	IRC 2012 W1/RES1 Design Level, <=2000 SQFT

Note: Essential Facilities (COM6, GOV2, and EDU1) if not Severe design level should be assigned Special design level (update HC to HS, MC to MS, and LC to LS) to prevent any increase in vulnerability.

Table C-8 Pre-IBC Era Seismic Design Level Matrix: Alaska

Construction Year	Pre-1966	1966 through 1992	1993 through 1998
UBC Zone 4 (MA 7)	Pre-Code (assume LC for W1)	Moderate-Code	High-Code (HS for Essential Facilities (COM6, GOV2, EDU1))
UBC Zone 3 (MA 6)	Pre-Code (assume LC for W1)	Low-Code (assume MC for W1)	Moderate-Code (MS for Essential Facilities (COM6, GOV2, EDU1))
UBC Zone 2b (MA 5)	Pre-Code	Low-Code	Moderate-Code
UBC Zone 1 (MA 2/3)	Pre-Code	Pre-Code	Low-Code
UBC Zone 0 (MA 1)	Pre-Code	Pre-Code	Pre-Code

Note: Assumes Good Friday 1964 earthquake and UBC 1991 as benchmarks, before code tracking was available.

Table C-9 IBC Era Seismic Design Level Matrix: California

Construction Year	1997 through 1999	2000 through 2008	2009 through 2011	2012 through 2014	2015 through 2020	2021 through 2023 (if any)
RES1, RES3A <=1,500 sqft (use 2000 for UBC 1994)	1994 UBC Design Level for W1 <= 2,000 sf	1997 UBC W1/RES1 Design Level, <=1500 SQFT	IRC 2006, W1 Design Level <=1500 SF	IRC 2009, W1 Design Level <=1500 SF	IRC 2012/ 2015, W1 Design Level <=1500 SF	Table F-13 and USGS SDS and SD1 contours
RES1, RES3A >1,500 sqft (use 2000 for UBC 1994)	1994 UBC Design Level for W1 > 2,000 sf	1997 UBC W1/RES1 Design Level, > 1500 SQFT	IRC 2006, W1 Design Level >1500 SF	IRC 2009, W1 Design Level >1500 SF	IRC 2012/ 2015, W1 Design Level >1500 SF	Table F-13 and USGS SDS and SD1 contours
Low-Rise Design Level	1994 UBC Design Level for Non-W1	1997 UBC Low-Rise Design Level	IBC 2006, Low-Rise Design Level	IBC 2009, Low-Rise Design Level	IBC 2012/2015, Low-Rise Design Level	Table F-10 and USGS SDS and SD1 contours
Mid-Rise/High-Rise Design Level	1994 UBC Design Level for Non-W1	1997 UBC Mid-Rise/High-Rise Design Level	IBC 2006, Mid-Rise/High-Rise Design Level	IBC 2009, Mid-Rise/High-Rise Design Level	IBC 2012/2015, Mid-Rise/High-Rise Design Level	Table F-10 and USGS SDS and SD1 contours

Note: Essential Facilities (COM6, GOV2, and EDU1) if not Severe design level should be assigned Special design level (update HC to HS, MC to MS, and LC to LS) to prevent any increase in vulnerability.

Table C-10 Pre-IBC Era Seismic Design Level Matrix: California

Construction Year	Pre-1941	1941 through 1975	1976 through 1996
UBC Zone 4 (MA 7)	Pre-Code (assume MC for W1)	Moderate-Code	High-Code (HS for Essential Facilities (COM6, GOV2, EDU1))
UBC Zone 3 (MA 6)	Pre-Code (assume MC for W1)	Moderate-Code	Moderate-Code (MS for Essential Facilities (COM6, GOV2, EDU1))

Note: W1 assumption will be implemented following assignment of earthquake specific building types

Table C-11 IBC Era Seismic Design Level Matrix: Hawaii

Construction Year	1994 through 2012	2013 through 2023
RES1, RES3A <=1,500 sqft (<=2,000 1994 UBC)	1994 UBC W1/RES1 Design Level, <= 2000 SQFT	IRC 2006 W1/RES1 Design Level, <=1500 SQFT
RES1, RES3A >1,500 sqft (>2,000 pre IBC)	1994 UBC W1/RES1 Design Level, > 2000 SQFT	IRC 2006 W1/RES1 Design Level, > 1500 SQFT
Low-Rise Design Level	1994 UBC Design Level for Non-W1	IBC 2006, Low-Rise Design Level
Mid-Rise/High-Rise Design Level	1994 UBC Design Level for Non-W1	IBC 2006, Mid-Rise/High-Rise Design Level

Note: Essential Facilities (COM6, GOV2, and EDU1) if not Severe design level should be assigned Special design level (update HC to HS, MC to MS, and LC to LS) to prevent any increase in vulnerability.

Table C-12 IBC Era Seismic Design Level Matrix: County of Honolulu

Construction Year	1994 through 2000	2001 through 2007	2008 through 2012	2013 through 2023
RES1, RES3A <=1,500 sqft (<=2,000 1994 UBC)	1994 UBC W1/RES1 Design Level, <= 2000 SQFT	1997 UBC W1/RES1 Design Level, <=1500 SQFT	IRC 2003 W1/RES1 Design Level, <=1500 SQFT	IRC 2006 W1/RES1 Design Level, <=1500 SQFT
RES1, RES3A >1,500 sqft (>2,000 1994 UBC)	1994 UBC W1/RES1 Design Level, > 2000 SQFT	1997 UBC W1/RES1 Design Level, >1500 SQFT	IRC 2003 W1/RES1 Design Level, > 1500 SQFT	IRC 2006 W1/RES1 Design Level, > 1500 SQFT
Low-Rise Design Level	1994 UBC Design Level for Non-W1	1997 UBC, Low-Rise Design Level	IBC 2003, Low-Rise Design Level	IBC 2006, Low-Rise Design Level
Mid-Rise/High-Rise Design Level	1994 UBC Design Level for Non-W1	1997 UBC, Mid-Rise/High-Rise Design Level	IBC 2003, Mid-Rise/High-Rise Design Level	IBC 2006, Mid-Rise/High-Rise Design Level

Note: Essential Facilities (COM6, GOV2, and EDU1), if not Severe design level, should be assigned a Special design level (update HC to HS, MC to MS, and LC to LS) to prevent any increase in vulnerability.

Table C-13 IBC Era Seismic Design Level Matrix: County of Kauai

Construction Year	1994 through 2001	2002 through 2008	2009 through 2012	2013 through 2023
RES1, RES3A <=1,500 sqft (<=2,000 1994 UBC)	1994 UBC W1/RES1 Design Level, <= 2000 SQFT	1997 UBC W1/RES1 Design Level, <=1500 SQFT	IRC 2003 W1/RES1 Design Level, <=1500 SQFT	IRC 2006 W1/RES1 Design Level, <=1500 SQFT
RES1, RES3A >1,500 sqft (>2,000 1994 UBC)	1994 UBC W1/RES1 Design Level, > 2000 SQFT	1997 UBC W1/RES1 Design Level, >1500 SQFT	IRC 2003 W1/RES1 Design Level, > 1500 SQFT	IRC 2006 W1/RES1 Design Level, > 1500 SQFT
Low-Rise Design Level	1994 UBC Design Level for Non-W1	1997 UBC Low-Rise Design Level	IBC 2003, Low-Rise Design Level	IBC 2006, Low-Rise Design Level
Mid-Rise/High-Rise Design Level	1994 UBC Design Level for Non-W1	1997 UBC Mid-Rise/High-Rise Design Level	IBC 2003, Mid-Rise/High-Rise Design Level	IBC 2006, Mid-Rise/High-Rise Design Level

Note: Essential Facilities (COM6, GOV2, and EDU1), if not Severe design level, should be assigned a Special design level (update HC to HS, MC to MS, and LC to LS) to prevent any increase in vulnerability.

Table C-14 Pre-IBC Era Seismic Design Level Matrix: Hawaii

Construction Year	Pre-1963	1964 through 1979	1979 through 1993
UBC Zone 4 (MA 7)	Pre-Code (assume LC for W1)	Moderate-Code	High-Code (HS for Essential Facilities (COM6, GOV2, EDU1)), Moderate-Code for RES1 and RES3A <2000 sqft
UBC Zone 3 (MA 6)	Pre-Code	Low-Code	Moderate-Code (MS for Essential Facilities (COM6, GOV2, EDU1)). Low-Code for RES1 and RES3A <2000 sqft
UBC Zone 2b (MA 5)	Pre-Code	Low-Code	Moderate-Code, Low-Code for RES1 and RES3A <2000 sqft
UBC Zone 1 (MA 2/3)	Pre-Code	Pre-Code	Low-Code

Note: Based primarily on County level adoption tracking presented in: https://cdn.ymaws.com/www.aiahonolulu.org/resource/resmgr/imported/Adv_Uniform%20State%20Wide%20Building%20Code%20Task%20Force%20Report.pdf.

Table C-15 IBC Era Seismic Design Level Matrix: Oregon Before 2006

Construction Year	1997 through 1999	1997 through 2000	2000 through 2004	2001 through 2003	2005 through 2007	2004 through 2005
RES1, RES3A <=1,500 sqft		1994 UBC W1/RES1 Design Level, <= 2000 SQFT		1997 UBC W1/RES1 Design Level, <=1500 SQFT		IRC 2000 W1/RES1 Design Level, <=1500 SQFT
RES1, RES3A >1,500 sqft		1994 UBC W1/RES1 Design Level, > 2000 SQFT		1997 UBC W1/RES1 Design Level, > 1500 SQFT		IRC 2000 W1/RES1 Design Level, > 1500 SQFT
Low-Rise Design Level	1994 UBC Design Level for Non-W1		1997 UBC Low-Rise Design Level		IBC 2003, Low-Rise Design Level	
Mid-Rise/High-Rise Design Level	1994 UBC Design Level for Non-W1		1997 UBC Mid-Rise/High-Rise Design Level		IBC 2003, Mid-Rise/High-Rise Design Level	

Note: Essential Facilities (COM6, GOV2, and EDU1) if not Severe design level should be assigned Special design level (update HC to HS, MC to MS, and LC to LS) to prevent any increase in vulnerability.

Table C-16 IBC Era Seismic Design Level Matrix: Oregon 2006 and Later

Construction Year	2008 through 2010	2006 through 2008	2011 through 2014	2009 through 2011	2015 through 2023	2012 through 2017	2018 through 2023
RES1, RES3A <=1,500 sqft		IRC 2003 W1/RES1 Design Level, <=1500 SQFT		IRC 2006 W1/RES1 Design Level, <=1500 SQFT		IRC 2009 W1/RES1 Design Level, <=1500 SQFT	IRC 2015 W1/RES1 Design Level, <=1500 SQFT
RES1, RES3A >1,500 sqft		IRC 2003 W1/RES1 Design Level, > 1500 SQFT		IRC 2006 W1/RES1 Design Level, > 1500 SQFT		IRC 2009 W1/RES1 Design Level, > 1500 SQFT	IRC 2015 W1/RES1 Design Level, > 1500 SQFT
Low-Rise Design Level	IBC 2006, Low-Rise Design Level		IBC 2009, Low-Rise Design Level		IBC 2012, Low-Rise Design Level		
Mid-Rise/High-Rise Design Level	IBC 2006, Mid-Rise/High-Rise Design Level		IBC 2009, Mid-Rise/High-Rise Design Level		IBC 2012, Mid-Rise/High-Rise Design Level		

Note: Essential Facilities (COM6, GOV2, and EDU1) if not Severe design level should be assigned Special design level (update HC to HS, MC to MS, and LC to LS) to prevent any increase in vulnerability.

Table C-17 Pre-IBC Era Seismic Design Level Matrix: Oregon

Construction Year	Pre-1975	1975 through 1991	1992 through 1996
UBC Zone 3 (MA 6)	Pre-Code	Low-Code (LS for Essential Facilities (COM6, GOV2, EDU1)).	Moderate-Code (MS for Essential Facilities (COM6, GOV2, EDU1)).
UBC Zone 2b (MA 5)	Pre-Code	Low-Code	Low-Code (LS for Essential Facilities (COM6, GOV2, EDU1)).

Note: Based primarily on adoption tracking presented in: https://www.oregon.gov/bcd/codes-stand/Documents/inform-2012-oregon-sesmic-codes-history.pdf. Based on no Zone 3 mapping in the Oregon UBC until 1991, MC is proposed for Zone 3 beginning with construction year 1992.

Table C-18 IBC Era Seismic Design Level Matrix: Utah

Construction Year	1996 through 1998	1999 through 2002	2003 through 2004	2005 through 2007	2008 through 2010	2011 through 2013	2014 through 2019	2020 through 2023	2020 through 2023
RES1, RES3A <=1,500 sqft	1994 UBC W1/RES1 Design Level, <= 2000 SQFT	1997 UBC W1/RES1 Design Level, <=1500 SQFT	IRC 2000 W1/RES1 Design Level, <=1500 SQFT	IRC 2003 W1/RES1 Design Level, <=1500 SQFT	IRC 2006 W1/RES1 Design Level, <=1500 SQFT	IRC 2009 W1/RES1 Design Level, <=1500 SQFT	IRC 2012/2015 W1/RES1 Design Level, <=1500 SQFT	IRC 2012/2015 W1/RES1 Design Level, <=1500 SQFT	
RES1, RES3A >1,500 sqft	1994 UBC W1/RES1 Design Level, > 2000 SQFT	1997 UBC W1/RES1 Design Level, > 1500 SQFT	IRC 2000 W1/RES1 Design Level, > 1500 SQFT	IRC 2003 W1/RES1 Design Level, > 1500 SQFT	IRC 2006 W1/RES1 Design Level, > 1500 SQFT	IRC 2009 W1/RES1 Design Level, > 1500 SQFT	IRC 2012/2015 W1/RES1 Design Level, > 1500 SQFT	IRC 2012/2015 W1/RES1 Design Level, > 1500 SQFT	
Low-Rise Design Level	1994 UBC Design Level for Non-W1	1997 UBC Low-Rise Design Level	IBC 2000, Low-Rise Design Level	IBC 2003, Low-Rise Design Level	IBC 2006, Low-Rise Design Level	IBC 2009, Low-Rise Design Level	IBC 2012/2015, Low-Rise Design Level		Table F-10 and USGS SDS and SD1 contours
Mid-Rise/High-Rise Design Level	1994 UBC Design Level for Non-W1	1997 UBC Mid-Rise/High-Rise Design Level	IBC 2000, Mid-Rise/High-Rise Design Level	IBC 2003, Mid-Rise/High-Rise Design Level	IBC 2006, Mid-Rise/High-Rise Design Level	IBC 2009, Mid-Rise/High-Rise Design Level	IBC 2012/2015, Mid-Rise/High-Rise Design Level		Table F-10 and USGS SDS and SD1 contours

Note: Essential Facilities (COM6, GOV2, and EDU1) if not Severe design level should be assigned Special design level (update HC to HS, MC to MS, and LC to LS) to prevent any increase in vulnerability.

Table C-19 Pre-IBC Era Seismic Design Level Matrix: Utah

Construction Year	Pre-1976	1976 through 1978	1979 through 1995
UBC Zone 3 (MA 6)	Pre-Code	Low-Code (LS for Essential Facilities (COM6, GOV2, EDU1&2)).	Moderate-Code (MS for Essential Facilities (COM6, GOV2, EDU1)).
UBC Zone 2b (MA 5)	Pre-Code	Pre-Code	Low-Code (LS for Essential Facilities (COM6, GOV2, EDU1)).
UBC Zone 1 (MA 3)	Pre-Code	Pre-Code	Pre-Code

Note: Based primarily on adoption tracking presented in: https://www.usu.edu/dps/emergency/files/Earthquake-Handbook.pdf

Table C-20 IBC Era Seismic Design Level: Washington

Construction Year	1996 through 1998	1999 through 2004	2005 through 2007	2005 through 2008	2008 through 2010	2009 through 2010	2011 through 2013	2014 through 2021	2022 through 2023
RES1, RES3A <=1,500 sqft	1994 UBC W1/RES1 Design Level, <= 2000 SQFT	1997 UBC W1/RES1 Design Level, <=1500 SQFT		IRC 2003 W1/RES1 Design Level, <=1500 SQFT		IRC 2009 W1/RES1 Design Level, <=1500 SQFT	IRC 2009 W1/RES1 Design Level, <=1500 SQFT	IRC 2012/15 W1/RES1 Design Level, <=1500 SQFT	Table F-10 and USGS SDS and SD1 contours
RES1, RES3A >1,500 sqft	1994 UBC W1/RES1 Design Level, > 2000 SQFT	1997 UBC W1/RES1 Design Level, > 1500 SQFT		IRC 2003 W1/RES1 Design Level, > 1500 SQFT		IRC 2009 W1/RES1 Design Level, > 1500 SQFT	IRC 2009 W1/RES1 Design Level, > 1500 SQFT	IRC 2012/15 W1/RES1 Design Level, > 1500 SQFT	Table F-10 and USGS SDS and SD1 contours
Low-Rise Design Level	1994 UBC Design Level for Non-W1	1997 UBC Low-Rise Design Level	IBC 2003, Low-Rise Design Level		IBC 2006, Low-Rise Design Level		IBC 2009, Low-Rise Design Level	IBC 2012/15, Low-Rise Design Level	Table F-10 and USGS SDS and SD1 contours
Mid-Rise/High-Rise Design Level	1994 UBC Design Level for Non-W1	1997 UBC Mid-Rise/High-Rise Design Level	IBC 2003, Mid-Rise/High-Rise Design Level		IBC 2006, Mid-Rise/High-Rise Design Level		IBC 2009, Mid-Rise/High-Rise Design Level	IBC 2012/15, Mid-Rise/High-Rise Design Level	Table F-10 and USGS SDS and SD1 contours

Note: Essential Facilities (COM6, GOV2, and EDU1) if not Severe design level should be assigned Special design level (update HC to HS, MC to MS, and LC to LS) to prevent any increase in vulnerability.

Table C-21 Pre-IBC Era Seismic Design Level Matrix: Washington

Construction Year	Pre-1976	1976 through 1978	1979 through 1994
UBC Zone 3 (MA 6)	Pre-Code (use Moderate Code starting at construction year 1953 for the City of Seattle)	Low-Code (LS for Essential Facilities (COM6, GOV2, EDU1)), use MC for Seattle	Moderate-Code (MS for Essential Facilities (COM6, GOV2, EDU1)).
UBC Zone 2b (MA 5)	Pre-Code	Pre-Code	Low-Code (LS for Essential Facilities (COM6, GOV2, EDU1)).

Note: Based primarily on adoption tracking presented in https://www.eeri.org/images/sesi/WashingtonBuildingCodeHistory-Rev_2-09-2017.pdf and http://clerk.ci.seattle.wa.us/search/