Data Standardization Guidelines for Loss Estimation – Populating Inventory Databases for HAZUS®MH MR-1

March 2006

Prepared for:

California Governor's Office of Emergency Services
Henry R. Renteria, Director

ImageCat, Inc.

ABS Consulting

OES CALIFORNIA
Governor's Office of Emergency Services

Data Standardization Guidelines for Loss Estimation – Populating Inventory Databases for HAZUS®MH MR-1

March 2006

Prepared for:

California Governor's Office of Emergency Services
3650 Schriever Avenue
Mather, CA 95655

Prepared by:

ImageCat, Inc.
400 Oceangate, Suite 1050
Long Beach, CA 90802 USA
IC Project No. 040803.01

ABS Consulting
300 Commerce Drive, Suite 200
Irvine, CA 92602 USA
ABSG Project No. 1382212

Contents

Appendices

List of Tables

List of Figures

1. Introduction

1.1 Project Objectives

Earthquakes and other disasters are infrequent events with the potential to cause significant economic losses and human suffering. To better prepare for and mitigate the damage from these disasters, state and local governments must be armed with knowledge of their potential effects. Engineers and scientists have contributed to the development of a number of useful tools and methods designed to facilitate planning and mitigation to reduce future losses from earthquakes.

HAZUS® (HAZards U.S.) is a standardized, nationally applicable earthquake loss estimation methodology and public domain software package developed for the Federal Emergency Management Agency (FEMA) by the National Institute of Building Sciences (NIBS). First released as HAZUS®97, significant updates followed, resulting in the more widely used version known as HAZUS®99, as well as two enhanced service releases; HAZUS®99 Service Release 1.0 (2001) and HAZUS®99 Service Release 2.0 (2002). The latest version of HAZUS®, HAZUS®MH, provides updated inventory data and new flood and hurricane modeling capability. HAZUS®MH V1.0 was released in January of 2004, followed by the release of HAZUS®MH MR-1 (Maintenance Release 1) in January, 2005. These guidelines focus on HAZUS®MH MR-1 (throughout this document, the phrases HAZUS® and HAZUS®MH MR-1 are used interchangeably). Local, state and federal government officials use HAZUS®MH for earthquake-related mitigation, emergency response, and recovery planning. Default data built into HAZUS®MH allows a user to run a simplified or "Level 1" analysis, without collecting additional data (i.e. "straight out of the box"). However, in many cases, the quality of default national data delivered with the software is less than optimal; it may originate from agencies other than FEMA, having been collected for applications other than earthquake loss estimation. Accordingly, the accuracy of HAZUS®MH results can be greatly improved with the input of various "user-supplied" data. An enhanced analysis is usually referred to as a "Level 2" analysis.

Collecting and updating data in HAZUS®MH can present a major challenge. With the aim of facilitating a comprehensive and standardized approach to loss estimation for the State, the California Governor's Office of Emergency Services funded a *two-phase* project to develop and implement guidelines for updating key databases in HAZUS®MH. *Phase One* of the Data Standardization Project, completed in June of 2004, was focused on prioritizing data collection efforts for the regional building inventory, transportation and utility lifelines within HAZUS®99. Also included in the *Phase One* Guidelines were tips for updating and verifying databases, step-by-step instructions on how to update the regional building inventory, and "lessons learned" by the Project Team in previous HAZUS®99 applications.

The ***Phase Two*** study addresses the implementation of procedures suggested in the *Phase One* Guidelines, and initiates the process of consistent and comprehensive database

development for loss estimation within California. Objectives for the *Phase Two* guidelines and standards development process were identified as follows:

1. Pilot test the approach suggested by the Phase One Guidelines by reviewing in detail available data for 10 pilot study areas, to be selected in conjunction with the California Office of Emergency Services (OES), and applying the suggested improvements for at least 2 areas.

2. Extend the Phase One Guidelines to address HAZUS®MH MR-1.

3. Build a "Building Stock Translation Utility" to facilitate modification of HAZUS®MH mapping schemes in the simpler HAZUS®99 format, and convert the results to HAZUS®MH MR-1 format.

4. "Calibration" of HAZUS®MH for the San Simeon Earthquake, to suggest an approach for the most realistic real-time loss estimates in similar areas in future events.

1.2 Intended Users and How to Use this Document

Users of this guide may include: emergency managers, GIS analysts, seismologists, geologists, city planners, and structural engineers, whom it is assumed have little or no prior experience *customizing* HAZUS®MH. For those who will be implementing the documented data enhancements, familiarity with the HAZUS®MH software and methodology is essential. Users should also be familiar with GIS concepts, or have GIS staff available. For high-level end-users of HAZUS®MH outputs (e.g., at the policy-level), detailed knowledge of the program's inner workings is not required, although general familiarity with the results is important. Notably, the guidelines presented in this document can be used to support the State of California's Disaster Assistance Program, which helps local governments become eligible for federal assistance after major disasters. Risk assessments that incorporate HAZUS®MH results will also help local governments become eligible for Stafford Act Disaster Assistance and comply with the mitigation planning requirements of the Disaster Mitigation Act of 2000 (DMA2000).

This document is an update of the *Phase One* guidelines to reflect the requirements of HAZUS®MH MR-1. It is designed to *simplify*, *prioritize*, and *facilitate* data collection for updating the HAZUS®MH MR-1 data tables. It walks the user through the process of updating HAZUS®MH MR-1 default databases, providing guidelines for prioritizing data collection efforts and presents a roadmap for data collection. Although this guide focuses on building stock and lifeline databases, the general principles are applicable to all HAZUS®MH data types. A potential user should understand the changes between HAZUS®99 and HAZUS®MH in the database structure for both lifelines and regional building inventories. These changes have simplified some data updates, which can now be made through the program interface. However, updating and replacing data outside of the HAZUS®MH interface is more complex. This guide also discusses custom tools developed for this project, designed to facilitate the update process. Finally, this

introductory chapter provides a summary of the limitations of these guidelines and other important considerations.

Table 1.1 outlines a basic approach recommended for an effective Level 2 loss estimation using HAZUS®MH MR-1. The table lists the recommended steps for updating datasets and identifies the appropriate sections in this guide where these procedures are described.

Table 1.1. Instructions for Updating HAZUS®MH Data

Data Type	Recommended Steps	Guideline Section
Transportation and utility lifeline data	• Review default data sets for a HAZUS®MH MR-1 study region. • Prioritize data collection efforts for lifelines using the priority-rating scheme. Identify lifeline tables with high and medium overall priority in the loss estimation process. • Review minimum data requirements, key fields, data type, source, and update efforts for the HAZUS®MH lifeline tables that are of high and medium priority. • Update lifeline tables according to the guidelines. • Verify the updated lifeline data tables.	Section 2.3 Section 3.1, Section 3.2 Appendix A and HAZUS®MH MR-1 Technical Manual, Appendix F (DHS/FEMA, 2005) Section 4, Appendix A Section 6
Building inventory data	• Review default data sets for a particular study region as described in Section 2.4, "Building Inventory Data in HAZUS®MH MR-1." (Advanced users are referred to Appendix F of the HAZUS Technical Manual, "Data Model Dictionary" for additional details.) • Review the list of candidate modifications to building inventory data. • Select the modification or a set of modifications that are relevant to the building stock for the particular study region. Use available tools, such as the Mapping Scheme Converter (MaSC) and the Building Inventory Replacement Tool (BIRT), to facilitate updates. For example, it might be useful to update the census tract-based "Square Footage – Occupancy" table from Assessor's data (using BIRT) for the study region because the county assessor's database is complete for that area. • Verify the updated building data tables with the help of various methods.	Section 2.4, and HAZUS®MH MR-1 Technical Manual, Appendix F (DHS/FEMA, 2005) Section 3.3, Section 5 Section 5, Appendix B (MaSC) and Appendix C (BIRT) Section 6

For users with limited HAZUS®MH experience, Chapter 2 provides an overview of the HAZUS®MH methodology and its component modules. The differences and similarities between HAZUS®99 and HAZUS®MH are presented in Section 2.2. Lifeline and transportation databases are introduced in Section 2.3 (with detailed information concerning specific tables presented in Appendix A). Section 2.4 provides a discussion of the HAZUS®MH MR-1 building inventory data for reference when updating the building inventory.

All users of this guide are advised to review the guidelines for the prioritization of data collection presented in Chapter 3 which are based on a comprehensive review of the default data in HAZUS®MH MR-1. These guidelines provide the user with an effective tool to optimize subsequent data collection efforts. The prioritization tables for lifelines in Section 3.2 provide a standard method for assessing the update priority for the various lifeline databases, based on the contribution to losses, ease of update, and data availability. In Section 3.3, a similar method is used to assess the process of updating the data on the general building stock. Users may wish to adjust any given priority based on regional needs or data availability.

Chapter 4 of this document is intended as a technical guide for GIS users and provides guidance on locating alternate data sources and updating the default lifeline data in HAZUS®MH MR-1. These are general guidelines, and include discussions on the approach for collecting and developing these databases. Section 4.1 outlines the sources of HAZUS®MH data that might be useful in supplementing the default lifeline data sets. This includes data sources documented in the *Phase One* as well as additional data sources obtained during the *Phase Two* study. Section 4.2 describes in detail the update procedures for HAZUS®MH MR-1 lifeline tables. In addition, a summary of common database principles dealing with spatial elements and process automation, are discussed in Sections 4.3.

Chapter 5 addresses the process of updating the default building inventory data in HAZUS®MH MR-1. Unlike HAZUS®99, which stored inventory data in readily accessible .DBF files, HAZUS®MH, stores all database information in SQL Server format using Microsoft's free SQL Server MSDE 2000. Accessing these data tables directly requires special software, such as Microsoft's SQL Server, and is not generally recommended for any but the most advanced user. However, to facilitate the process of updating relevant information in the HAZUS®MH MR-1 SQL server database, the current Data Standardization project has generated two tools designed for a more typical user (although some database skills are required); the Mapping Scheme Converter (MaSC) and the Building Inventory Replacement Tool (BIRT). Chapter 5 provides a list of suggested specific updates to the default building inventory data, based on the range of alternate datasets available to the user, as well as instructions for their implementation.

Finally, Chapter 6 of this document provides suggestions for verifying the enhanced data imported into HAZUS®MH MR-1, including a description of methods for data review (Section 6.1), mapping data (Section 6.2), and summarizing the data using database and graphing programs (Section 6.3). Section 6.4 discusses how to verify replacement cost data, and Section 6.5 describes options for identifying potential problems with the input data. Section 6.6 includes a description of checking building data updates accomplished using the BIRT.

The Appendices provide supplementary information for the building and lifeline databases and loss estimation process. Appendix A identifies transportation and utility lifeline data requirements for both HAZUS®99 and HAZUS®MH. For each lifeline, the default data quality is assessed, and the required data fields are identified. Appendix B

describes the Mapping Scheme Converter (MaSC) tool, including the system requirements and steps required for running MaSC. Appendix C is a detailed *User Manual* for the Building Inventory Replacement Tool (BIRT).

1.3 Limitations of this Guide and Other Considerations

The limitations below describe important considerations that are outside the scope of this document.

1) Focus on Loss Estimation

The focus of this document is loss estimation. The prioritization of data collection for specific exposures has been explicitly driven by economic losses. The results generated from earthquake loss estimation methods such as HAZUS®MH are useful for response planning, mitigation, cost benefit analysis, and in the event of a disaster, for gauging the scope of the disaster in the immediate response period. However, loss estimates may not be appropriate or useful for some initial emergency response efforts. For example, warehouses at port facilities may contribute very little to total losses, but may be a key element in resource allocation after an event. HAZUS®MH databases contain fields for the contact information for essential facilities and schools. These fields may be blank, or the contact information may be out of date, but the lack of information has no impact on loss estimates. However, updating this data may be a high priority for response efforts by various agencies. Users will want to balance their data collection efforts for the economic loss-focused priorities laid out by these guidelines, with emergency response or other concerns for their specific agency or region.

2) Updating Additional Data

This guide focuses on regional building inventory databases and lifeline databases; it does not address seismic hazard data (e.g., liquefaction or landslide susceptibility data) or site-specific building databases, such as essential facilities. The following list outlines some of the other data that the user may want to consider updating within HAZUS®MH:

Soils – Updating the HAZUS®MH default soil database with data available from the California Geological Survey (CGS) can significantly improve the accuracy of HAZUS®MH loss estimates with only a modest effort (default values are uniform soil conditions throughout any study area). For California, better data can be obtained from CGS. Users can call the CGS at (916) 445-1825 and request a license agreement for the "HAZUS® compatible Preliminary Statewide Site Conditions Map for California" (Wills et al., 2000). For more site-specific information, local consultants and county geologists can be contacted to compile soil data.

Ground Motion - Within HAZUS®MH, "user-defined" ground motion data can be readily imported, effectively bypassing the HAZUS®MH ground motion estimation module. One source of this type of data is the U.S. Geological Survey (USGS). USGS ShakeMap regional ground motion estimates are available in a format developed specifically for use

in HAZUS®MH. For California, this data is accessible through the website for the California Integrated Seismic Network (www.cisn.org). These ground motion estimates are available for actual earthquake events, as well as for postulated earthquake scenarios.

Essential Facilities – Emergency or essential facilities are key to response and recovery efforts after a major event. These facilities include hospitals and medical care facilities, fire stations, police stations, emergency operations centers (EOC), and schools and universities. HAZUS®MH includes a limited default database for essential facilities. Data requirements for essential facilities in HAZUS®MH include location, occupancy class, seismic design level, construction quality, model building type, mapping scheme, and replacement cost data. Data can be collected from local fire or police departments, the American Hospital Association or the California Office of Statewide Health Planning and Development (OSHPD), and similar agencies. Updating essential facilities with more accurate information will improve damage and functionality estimates useful for emergency response.

Public Buildings – Individual public buildings are not in the HAZUS®MH default data. A detailed risk assessment of public buildings is required for compliance with the Disaster Mitigation Act of 2000. Analyzing the performance of government buildings is key to assessing response capabilities and for estimating potential Public Assistance needs after an event. The HAZUS®MH Advanced Engineering Building Module (AEBM) allows users to assess risk to building portfolios. Data required to analyze a portfolio of public buildings with the AEBM include: latitude and longitude of the building, HAZUS®MH model building type (structural classification), seismic design level, building quality (seismic performance level), replacement cost (in thousands of dollars), and total building square footage. For additional information, the user is referred to the AEBM Technical and User's Manual (DHS/FEMA, 2005).

Historic Buildings – Individual historic buildings are not in the HAZUS®MH default data. Many older communities throughout the state have an extensive inventory of historic buildings. Age and decay can be significant factors for the vulnerability of these buildings. This inventory of architecturally unique and interesting buildings represents a cultural resource that cannot be accurately quantified in terms of dollars. Finally, analysis of historic buildings requires special considerations, as their repair is governed by special regulations.

3) Need for the MaSC (Mapping Scheme Converter) and BIRT (Building Inventory Replacement Tool) Programs

Building inventories within HAZUS®MH MR-1 are represented by a number of related tables. Unlike HAZUS®99, which stored inventory database tables in easily accessible .DBF format, HAZUS®MH stores all database information in SQL Server format using Microsoft's free SQL Server MSDE 2000. Accessing these data tables directly requires special software, such as Microsoft's SQL Server, and is not recommended for any but the most advanced user.

One of the unfortunate consequences of the move to a new software platform and database format for multi-hazard application is the "disconnection" of the inventory tables, and the loss of "on the fly" functionality. That is, in HAZUS®99, a user could modify the inventory model tables (e.g., replacement cost model, location factor, typical building size) as well as the inventory tables themselves, and HAZUS®99 would recalculate all dependent tables "on the fly". Because of the complex interrelationships between the tables, and between hazards, this functionality is not available within HAZUS®MH. This means that there is no simple mechanism for the user to update underlying models that change over time (e.g., cost models), or to update a dependent table (e.g., building count) if the user should modify its source table (e.g., square footage).

To facilitate the process of updating relevant information in the HAZUS®MH MR-1 SQL server database, the current Data Standardization project has generated two tools;

- MaSC – the Mapping Scheme Converter, designed to allow users to edit HAZUS®99 mapping scheme tables in .dbf format, and import them into HAZUS®MH MR-1. MaSC is a stand alone tool that requires no additional software (See Appendix B for more information on MaSC).

- BIRT – the Building Inventory Replacement Tool (a "work around" for the table "disconnection" associated with HAZUS®MH) allows users to perform both Level 1 and Level 2 updates on the square footage, dollar exposure and building count tables in HAZUS®MH MR-1. To use BIRT, the user must have Microsoft Access 2002 (although BIRT will also operate in Microsoft Access 2003, with minor security setting modifications). Level 1 updates require no additional data; Level 2 updates are designed for more sophisticated users with access to Assessor's data (See Appendix C for more information on BIRT).

4) Electric Power – Regional Outage Model in HAZUS®MH

HAZUS®MH MR-1 produces damage state and dollar loss estimates for electric power facilities when default data is available, as well as for any user-input facilities. However, the electric power system outage model that produces estimates of the number of households without power is not functioning properly in HAZUS®MH MR-1. It is assumed that this problem will be corrected in HAZUS®MH MR-2.

2. HAZUS®MH MR-1: FEMA's Loss Estimation Software

2.1 Background on HAZUS®MH

HAZUS®MH is a GIS-based regional loss estimation tool developed under a cooperative agreement between FEMA and NIBS. Following extensive peer review, the program was initially released in 1997, with an additional major release in 1999. HAZUS®99 supported both the ArcView 3.x and MapInfo desktop GIS platforms. The latest multi-hazard version, HAZUS®MH MR-1, utilizes the ArcGIS platform; flood analysis requires the ArcGIS Spatial Analyst extension.

The HAZUS®MH earthquake module estimates ground shaking, building damage, casualties, and displaced persons by census tract, given the earthquake fault or epicenter magnitude and location[1]. Additionally, HAZUS®MH estimates site-specific damage to transportation systems and utilities, essential facilities, and custom building portfolios. Results from hypothetical scenarios are routinely used for emergency response training exercises, response plans, and resource needs assessments. Advanced users can use quantitative loss projections for planning purposes, such as cost benefit analysis of building codes or proposed mitigation efforts. After an event, HAZUS®MH provides an initial estimate of damage at the critical time when the severity and spatial distribution of damage is unclear.

2.1.1 Overview of the HAZUS®MH Methodology

Government agencies and researchers use HAZUS®MH for mitigation, emergency preparedness, and disaster response. The model produces quantitative estimates of losses to buildings and infrastructure, estimates of impact on the functionality of selected facilities, and casualty and other population impact estimates. Dollar losses include the direct repair costs for buildings and lifelines, as well as selected indirect economic losses. Functionality estimates include restoration time for key facilities, such as hospitals, highway bridges, water treatment plants, and electric power substations, and simplified system restoration assessments for potable water and electrical power networks[2]. Casualty estimates are provided by injury severity, and are not factored into quantitative estimates of dollar loss. The model also estimates losses due to fire-following earthquake, and the quantity of earthquake-related debris generated.

---

1 Alternatively, the user may import "user-supplied" hazard data, such as a ShakeMap generated by the USGS or other sources.

2 It should be noted that the electric power system outage model that produces estimates of the number of households without power is not functioning properly in HAZUS®MH MR-1. It is assumed that this problem will be corrected in HAZUS®MH MR-2.

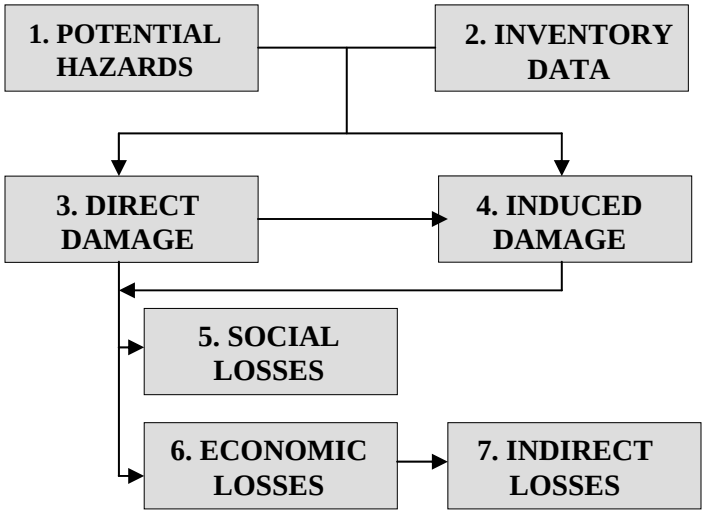


Figure 2.1. HAZUS®MH Modules for Earthquakes (Bouabid, et al., 2002)

Depending on the focus of a loss estimation study and the knowledge and expertise of the user, HAZUS®MH may be used to analyze losses at different levels of detail. The focus of a particular study could, for example, be the characterization of damage to the general building stock. It is likely that a user performing such a study would want to enhance the default building inventory data, using various methods and approaches (See Section 5). However, they may not wish to expend time or effort collecting improved lifeline data, which is not a focus. In this instance, the HAZUS®MH default data for lifelines would suffice.

2.1.2 HAZUS®MH Modules

HAZUS®MH consists of seven (7) interdependent modules, with output of some modules acting as input to others. The connectivity between the modules is represented by the diagram in Figure 2.1 (Bouabid, et al., 2002). The program is designed so that a user can adjust parameters of individual modules without adjusting all of the modules. Additional data can be imported or entered into the program to fit the needs of a particular study. For example, if the focus of a particular study is lifeline losses, a user can update these datasets, but utilize the unchanged default building inventory. However, users must be aware that soil and liquefaction data greatly affect lifeline estimates, and should be updated when these facilities are of concern. The following discussion summarizes each module. A detailed technical discussion can be found in the HAZUS®MH Technical Manual (DHS/FEMA, 2005), which is delivered digitally with the software package.

Potential Earth Science Hazard (PESH) – Estimates ground motion and ground failure from landslides, liquefaction, and surface fault rupture. This module can be greatly improved by including accurate soil data. Default data for soil is a uniform condition

throughout the study region, and no default liquefaction or landslide susceptibility data is provided with the software.

Inventory Data – HAZUS®MH is distributed with default data, including a database representing the general building stock across the entire U.S. that users can update with more detailed local data. The four inventory groups included in the default data set are general building stock, essential facilities, transportation lifelines, and utility lifelines.

Direct Damage – Estimates damage to the inventory data based on the exposure to hazards and the vulnerability of structures. Results are provided in the form of a probability that each facility is within a given damage state. Damage calculations are dependent upon both the PESH and the inventory data.

Induced Damage – Estimates selected secondary consequences of an earthquake event. Fire following earthquake (FFE) and accumulation of debris are the focus of this module. Induced damage calculations are dependent upon PESH (FFE) and direct damage (debris).

Social Losses – Estimates social losses in terms of casualties, displaced households, and short-term shelter needs. Social loss calculations are dependent upon demographic exposure and direct damage estimates.

Economic Losses – Estimates dollar losses from structural and nonstructural damage, contents damage, costs of relocation, losses to business inventory, capital-related losses, income losses, and rental losses. Economic losses are also calculated for direct damage and repair of transportation and utility lifelines. Economic loss calculations are dependent upon the direct damage estimates.

Indirect Losses – Evaluates the effects of earthquake losses on the long-term health of the regional economy. Indicators of indirect losses include change in income and employment. Indirect loss calculations are dependent upon building inventory loss and damage calculations, as well as selected lifeline performance.

The following section describes how this modular approach allows the HAZUS®MH user to perform different levels of analysis, ranging from estimates based on simplified models and default inventory data, to more refined studies based on detailed engineering and geotechnical data for a specific study region.

2.1.3 Levels of Analysis Using HAZUS®MH

HAZUS®MH defines "level of analysis" based upon how much of the model is customized for a specific purpose. The first level (Level 1) uses default inventory data and models. The second level of analysis (Level 2) requires replacement of inventory data and models with user-supplied data. The third level of analysis (Level 3) incorporates data and results from third-party studies. The following section briefly summarizes these analysis

levels. The HAZUS®MH Technical Manual (DHS/FEMA, 2005) provides a more detailed description of the three (3) analysis levels.

Level 1: Analysis Based on Default Data and Models

The basic level of analysis uses only the default databases provided with the HAZUS®MH software. For a Level 1 analysis, direct economic and social losses associated with the general building stock and lifelines are computed. Indirect economic impacts are calculated based on assumed economic parameters that may or may not accurately reflect the true characteristics of the region. Results from a Level 1 analysis can be greatly improved with supplemental data. Results from a Level 1 analysis should generally be used with caution.

Level 2: Analysis Based on User supplied Data

This higher-level analysis is based on user-supplied inventory and/or hazard data, and should produce results that more realistically reflect local conditions. A Level 2 analysis can be an analysis where only a single default data set is updated, or an analysis where most of the data are updated, reflecting significant work. Users should refer to Chapter 3 of this Guidelines document for a discussion of prioritizing Level 2 data collection efforts.

Level 3: Analysis Based on Advanced Data and Models

This level of analysis incorporates results from engineering and economic studies that use independent methods and software. For this level of analysis, technical experts work independently to acquire data, perform detailed analyses, and assess damage and losses. Based on the results of these analyses, experts assist users in gathering more extensive data to update or adjust the underlying models and data.

2.1.4 Limitations of HAZUS®MH

FEMA recognizes that there are limitations associated with the HAZUS®MH program. The following list of limitations has been taken directly from the HAZUS®MH documentation (from the "Message to Users" contained in the Preface to the HAZUS®MH MR-1 Technical Manual, DHS/FEMA, 2005):

"Users should be aware of the following specific limitations:

- While the HAZUS®MH Earthquake Model can be used to estimate losses for an individual building, the results must be considered as average for a group of similar buildings. It is frequently noted that nominally similar buildings have experienced vastly different damage and losses during an earthquake.

- When using embedded inventories, accuracy of losses associated with lifelines may be less than for losses from the general building stock. The embedded databases and

assumptions used to characterize the lifeline systems in a study region are necessarily incomplete and oversimplified.

- Based on several initial studies, the losses from small magnitude earthquakes (less than M6.0) centered within an extensive urban region appear to be overestimated.

- Because of approximations in modeling of faults in California, there may be discrepancies in motions predicted within small areas immediately adjacent to faults.

2.2 HAZUS®99 and HAZUS®MH Compared

While this *Phase Two* guide addresses the use of HAZUS®MH**,** the *Phase One* guide focused on HAZUS®99. HAZUS®MH is an updated version of HAZUS®99. The HAZUS®MH program includes additional modules to analyze flood and hurricane hazards, as well as modules to utilize results of third party software to analyze air dispersion (ALOHA/ MARPLOT) and river mechanics (FLDWV/FLDVIEW). It should be noted that HAZUS®MH does not include a tool to analyze damage to water networks, such as the POWSAM (Potable Water System Analysis Model) module that was included in HAZUS®99.

Potential users should take into account a number of changes between the two versions of HAZUS®MH in terms of component modules, inventory data, usability, and other factors. As summarized in Table 2.1, many of the databases have been updated in HAZUS®MH - most significantly building inventories based on census data. In addition, many of the lifeline datasets have been removed due to security concerns. HAZUS®99 required either MapInfo 6.0 or the ArcView 3.2 platform. HAZUS®MH does not support MapInfo users, largely due to raster processing requirements of the flood module. HAZUS®MH runs on the ArcGIS platform. HAZUS®MH study regions created in HAZUS®99 cannot be imported into HAZUS®MH. FEMA is planning to discontinue support of HAZUS®99 in the near future.

Table 2.1. HAZUS®99 and HAZUS®MH Comparison

	HAZUS®99	HAZUS®MH MR-1
Modules	Earthquake, additional module to assess damage to water networks (Potable Water System Analysis Model - POWSAM)	Earthquake, Flood, Wind, External Third Party models
Inventory Data (Buildings, Essential Facilities, and Lifelines)	- 1990 data for square footage and demographics from U.S. Census, and Dun and Bradstreet business data - 1994 replacement cost models based on R.S. Means - 1990 inventory data for essential facilities and lifeline systems	- 2000 data for square footage and demographics from U.S. Census, and Dun and Bradstreet business data - 2002 replacement cost models based on R.S. Means - 2000 or later inventory data for essential facilities and lifeline systems
Usability/ Other	- ArcView and MapInfo platforms - Faster running time than HAZUS®MH - Updating underlying tables is straightforward. Table editing or replacement may require file reformatting.	- ArcGIS platform - Longer running time than HAZUS®99 for the same study region - Update process simplified through use of database tools such as Microsoft Access, although building inventory and mapping schemes data have become more complex.

In addition to the major HAZUS®MH updates listed in Table 2.1, methodological changes have also been made:

- In HAZUS®MH, the specific occupancy classification scheme has been refined for the multi-family residential category. The multi-family dwellings (RES3 in HAZUS®99) are split into six categories in HAZUS®MH:

  i) Duplex (RES3A)
  ii) Triplex / Quads (RES3B)
  iii) Multi-family dwellings - 5 to 9 units (RES3C)
  iv) Multi-family dwellings - 10 to 19 units (RES3D)
  v) Multi-family dwellings - 20 to 49 units (RES3E) and
  vi) Multi-family dwellings - 50+ units (RES3F).

- The attributes in the demographics data have been expanded in HAZUS®MH to include: gender information, additional income brackets, the number of students, and a building count by age.

- New 2002 USGS probabilistic ground shaking maps and new USGS attenuation functions have replaced the older versions in HAZUS®99.

Tables A.1 and A.2 in Appendix A present the differences between HAZUS®99 and HAZUS®MH in terms of the default lifeline inventory data and various model requirements. Furthermore, two major new modules have been added to HAZUS®MH; the flood and wind loss models.

i) *Flood Model:* The HAZUS®MH Flood Model methodology consists of two basic analytical modules: flood hazard analysis, and flood loss estimation analysis. In the hazard analysis phase, characteristics such as frequency, discharge, and ground elevation are used to model the spatial variation of flood depth. In the loss estimation phase, damage is calculated based on the results of the hazard analysis through the use of depth-damage curves.

ii) *Wind Model*: The HAZUS®MH Wind Model is based on a hazard-load-resistance-damage-loss methodology developed from an individual risk framework. The basic components include the hazard model, load model, and resistance models.

Detailed documentation concerning the Flood and Wind models and input data is available in the HAZUS®MH User's Manual and Technical Manual. According to FEMA, HAZUS®MH is a work in progress. Additional damage and loss data from actual events and further experience in using the software will contribute to improvements in future releases.

2.3 Lifeline Inventory Data in HAZUS®MH MR-1

Unlike HAZUS®99, which stored lifeline inventory attribute data in easily accessible dBase format, HAZUS®MH stores all database information in SQL Server using Microsoft's free SQL Server MSDE 2000. Accessing these data tables directly requires special software, such as Microsoft's SQL Server. The geographic data stored within HAZUS®MH has been upgraded from ESRI shapefiles to an ArcGIS geodatabases, an ESRI specific extension of the Microsoft Access database. This presents new challenges for updating the underlying data and is recommended for advanced users only. Please see Section 4.2: Updating Default Lifeline data in HAZUS®MH for a description of how to import lifeline data into HAZUS®MH.

2.3.1 Transportation System Default Data and Sources

Transportation system inventory data in HAZUS®MH includes highways, railways, light rail, bus systems, ports, ferry systems and airports. Each transportation system category is broken down further into facility components (see Table 2.2). For example, the railway system consists of tracks/roadbeds, bridges, tunnels, urban stations, maintenance

facilities, fuel facilities, and dispatch facilities. Damage state probabilities and losses are computed for each component of each lifeline. Appendix A identifies transportation lifeline data sources and requirements for HAZUS®MH.

The default highways in HAZUS®MH are derived from the 2000 U.S. Census Bureau TIGER data (Topologically Integrated Geographic Encoding and Referencing system). The highway bridge and tunnel data are derived from the National Bridge Inventory (NBI) 2001 database.

The railway tracks, bridges, and facilities in the default HAZUS®MH railway system database are derived from various data sources. These include the 2000 U.S. Census Bureau TIGER data, the 2001 NBI database, 2000 USDOT Bureau of Transportation Statistics' Intermodal Terminal Facilities Database (2000) and 1998 Amtrak Stations database.

The light rail data in HAZUS®MH is derived from the 2000 Fixed-Guideway Transit and Ferry Network database from the USDOT Bureau of Transportation Statistics. The light rail bridge data is derived from the National Bridge Inventory (NBI) 2001 database. There is no default light rail tunnel and facility data in HAZUS®MH.

The default bus facilities database in HAZUS®MH is derived from a 2001 database created by InfoUSA Inc. The default port and harbor facility data, as well as ferry data in HAZUS®MH is developed from the 2000 Port & Waterway Facilities database provided by the U.S. Army Corps of Engineers CEIWR (Corp of Engineers Institute of Water Resources), Navigation Data Center, Ports and Waterways Division. The default airport runway and facility database is developed from 1995 data obtained from the USDOT Bureau of Transportation Statistics, Federal Aviation Administration (FAA).

Table 2.2. HAZUS®MH Transportation Lifeline Data Tables

Item No.	Facility	Facility Components	HAZUS®MH Tables[3]
1	Highway Segments		hzHighwaySegment, eqHighwaySegment
2	Highway Bridges		hzHighwayBridge, eqHighwayBridge, flHighwayBridge
3	Highway Tunnels		hzHighwayTunnel, eqHighwayTunnel
4	Railway Track Segments		hzRailwaySegment, eqRailwaySegment
5	Railway Bridges		hzRailwayBridge, eqRailwayBridge, flRailwayBridge
6	Railway Tunnels		hzRailwayTunnel, eqRailwayTunnel
7	Railway Facilities	*Rail Urban Station*	hzRailFlty, eqRailFlty
		Rail Fuel Facility	
		Rail Dispatch Facility	
		Rail Maintenance Facility	
8	Light Rail Track Segments		hzLightRailSegment, eqLightRailSegment
9	Light Rail Bridges		hzLightRailBridge, eqLightRailBridge, flLightRailBridge
10	Light Rail Tunnels		hzLightRailTunnel, eqLightRailTunnel
11	Light Rail Facilities	*DC Substation*	hzLightRailFlty, eqLightRailFlty
		Light Rail Dispatch Facility	
		Light Rail Maintenance Facility	
12	Bus Facilities	*Bus Urban Station*	hzBusFlty, eqBusFlty
		Bus Fuel Facility	
		Bus Dispatch Facility	
		Bus Maintenance Facility	

3 Tables accessed through HAZUS®MH interface and SQL Server in the background. The SQL Server running in the background of HAZUS®MH is "HAZUSPLUSRVR" and the database containing study region specific lifeline tables is "syHazus"

The geographic data for all the Transportation Lifeline tables in HAZUS®MH is stored in the TRN.MDB Geodatabase.

The geographic data for all the Transportation Utility tables in HAZUS®MH is stored in the UTIL.MDB Geodatabase.

Item No.	Facility	Facility Components	HAZUS®MH Tables[3]
13	Ports and Harbors Facilities	*Waterfront Structures*	hzPortFlty, eqPortFlty
		Cranes/Cargo handling equipment	
		Fuel Facility	
		Warehouses	
14	Ferry Facilities	*Waterfront Structures*	hzFerryFlty, eqFerryFlty
		Passenger terminals	
		Dispatch facility	
		Fuel facility	
		Maintenance facilities	
15	Airports Facilities	*Control Towers*	hzAirportFlty, eqAirportFlty
		Terminal Buildings	
		Parking Structure	
		Fuel facility	
		Maintenance & Hanger facilities	
		Airport-General	
		Heliport Facilities	
		Seaport/ Stolport/Gliderport	
16	Airports Runways		hzRunway, eqRunway

2.3.2 Utility System Default Data and Sources

Utility system inventory data in HAZUS®MH includes potable water, wastewater, electric power, communications, oil, and natural gas. Each of the utility system categories is broken down further into facility components (see Table 2.3). For example, potable water systems consist of supply, storage, transmission, and distribution components. Damage state probabilities and losses are computed for each component of each lifeline. In addition, simplified network performance assessments can be carried out for potable water and electrical systems. Appendix A identifies utility lifeline data sources and requirements for HAZUS®MH.

The default potable water pipeline database in HAZUS®MH has limited data only for the State of South Carolina. There is no default wastewater pipeline data in HAZUS®MH. The potable water distribution and the wastewater collection databases in HAZUS®MH are derived from the 2000 U.S. Census Bureau TIGER file. The default potable water and wastewater facility database was developed using data obtained from 2001 Environmental Protection Agency (EPA) Envirofacts Data Warehouse and the Location Reference Tables (LRT) tool.

The default oil and natural gas transmission pipeline databases in HAZUS®MH have limited data only for the State of South Carolina. The natural gas distribution database is derived from the 2000 U.S. Census Bureau TIGER file. The default oil and natural gas facilities database was developed using 2001 Environmental Protection Agency (EPA) Envirofacts Data Warehouse and the Location Reference Tables (LRT) tool.

The default electric power facilities database was developed from the 2001 Environmental Protection Agency (EPA) Envirofacts Data Warehouse and the Location Reference Tables (LRT) tool. The communications facilities data was developed from the 2001 FCC Broadcast Auxiliary Microwave database. There is no default electrical power and communication circuits data included in HAZUS®MH.

Table 2.3. HAZUS®MH Utility Lifeline Data Tables

Item No.	Facility	Facility Components	HAZUS®MH Tables[3]
1	Potable Water Pipeline Segments		hzPotableWaterPl, eqPotableWaterPl, flPotableWaterPl
2	Potable Water Distribution Lines		hzTract, eqPotableWaterDl
3	Potable Water Facilities	*Water Treatment Plants* *Wells* *Pump Stations* *Storage Tanks* *Control Vault/Control Station***	hzPotableWaterFlty, eqPotableWaterFlty, flPotableWaterFlty
4	Wastewater Pipeline Segments		hzWasteWaterPl, eqWasteWaterPl, flWasteWaterPl
5	Wastewater Distribution Lines		hzTract, eqWasteWaterDl
6	Waste Water Facilities	*Wastewater Treatment Plants* *Lift Stations* *Control Vault/Control Station* ***	hzWasteWaterFlty, eqWasteWaterFlty, flWasteWaterFlty
7	Oil Pipelines Segments		hzOilPl, eqOilPl, flOilpl
8	Oil Systems Facilities	*Refineries* *Pumping Plants* *Tank Farms* *Control Vault/Control Station* *=?	hzOilFlty, eqOilFlty,flOilFlty
9	Natural Gas Pipelines Segments		hzNaturalGasPl, eqNaturalGasPl, flNaturalGasPl
10	Natural Gas Distribution Lines		hzTract, eqNaturalGasDl
11	Natural Gas Facilities	*Compressor Stations* *Control Vault/Control Station* **	hzNaturalGasFlty, eqNaturalGasFlty, flNaturalGasFlty

Item No.	Facility	Facility Components	HAZUS®MH Tables[3]
12	Electric Power Facilities	*Substations*	hzElectricPowerFlty, eqElectricPowerFlty, flElectricPowerFlty
		Generating Facilities	
13	Electric Power Distribution Lines		
14	Communication Facilities	*Central Office/ Switching Stations*	hzCommunicationFlty, eqCommunicationFlty
		Radio/ TV Station	
		Weather Station	
		Other Communication Facility	
15	Communication Distribution Cables		

** Damage to control vaults is assessed in the HAZUS-MH flood model, but not in the HAZUS-MH earthquake model.

2.4 Building Inventory Data in HAZUS®MH MR-1

In order to estimate regional building damage and economic losses, HAZUS®MH MR-1 is delivered with a default building inventory database intended to represent the entire building stock of any given community. This data is aggregated data, i.e., the database tabulates attributes such as the total building square footage and dollar exposure by census tract, rather than on a building-by-building basis.

This aggregate database was developed from nationally available data, including: 2000 census data (for residential structures), and data purchased from Dun & Bradstreet (for commercial and industrial structures). This represents an update from the 1990 census data used in HAZUS®99. For more information on the development of the default building inventory data, the user is encouraged to review the HAZUS®MH MR-1 Technical Manual (DHS/FEMA, 2005).

Building inventories within HAZUS®MH MR-1 are represented by a number of related tables. Unlike HAZUS®99, which stored inventory database tables in easily accessible .DBF format, HAZUS®MH stores all database information in SQL Server format using Microsoft's free SQL Server MSDE 2000. Accessing these data tables directly requires special software, such as Microsoft's SQL Server, and is not recommended for any but the most advanced user.

One of the unfortunate consequences of the move to a new software platform and database format for multi-hazard application is the "disconnection" of the inventory tables, and the loss of "on the fly" functionality. That is, in HAZUS®99, a user could modify the inventory model tables (e.g., replacement cost model, location factor, typical building size) as well as the inventory tables themselves, and HAZUS®99 would recalculate all dependent tables "on the fly". Because of the complex interrelationships between the tables, and between hazards, this functionality is not available within

HAZUS®MH. This means that there is no simple mechanism for the user to update underlying models that change over time (e.g., cost models), or to update a dependent table (e.g., building count) if the user should modify its source table (e.g., square footage).

To facilitate the process of updating relevant information in the HAZUS®MH MR-1 SQL server database, the Data Standardization project has generated two tools;

- MaSC – the Mapping Scheme Converter Tool, designed to allow users to edit HAZUS®99 mapping scheme tables in .dbf format, and import them into HAZUS®MH MR-1. MaSC is a stand-alone tool that requires no additional software.
- BIRT – the Building Inventory Replacement Tool (a "work around" for the table "disconnection" associated with HAZUS®MH) allows users to perform both Level 1 and Level 2[4] updates on the square footage, dollar exposure and building count tables in HAZUS®MH MR-1. Level 1 updates require no data; Level 2 updates are designed for more sophisticated users with access to Assessor's data. To use BIRT, the user must have Microsoft Access 2002 or 2003.

Both these tools are described in greater detail in Appendix B and Appendix C respectively.

2.4.1 Square Footage Distribution by Occupancy Class and Census Tract

This data table is accessed through the HAZUS®MH MR-1 "Inventory", "General Building Stock", "Square Footage" menu selections. The occupancy class - square footage table provides total building square footage by census tract for each of the 33[5] HAZUS®MH occupancy classes given in Table 2.4. This data is the fundamental basis of all building damage and loss calculations within HAZUS®MH. As mentioned previously, the default square footage building inventory data was developed from 2000 census data for residential exposure, and business data from Dun & Bradstreet for non-residential exposure. This is "proxy" data. For example, for residential uses, assumptions regarding square footage per housing unit were used to estimate building stock exposure from available census data.

4 Level 1 and Level 2 updates in BIRT are defined similarly to HAZUS; Level 1 requires no additional data and Level 2 requires user-input data.
5 HAZUS®99 had 27 occupancy classes while HAZUS®MH has 33; the increase in occupancies results from the disaggregation of the RES3 occupancy (multi-family dwellings) into 6 sub-classes, based on number of units. See Table 5-1.

Table 2.4. HAZUS®MH Occupancy Classes (DHS/FEMA, 2005)

Class Number	HAZUS®MH Occupancy Class	Description
1	RES1	Single Family Dwelling
2	RES2	Mobile Home
3	RES3A	Multi-Family Dwellings: Duplex
4	RES3B	Multi-Family Dwellings: 3 - 4 units
5	RES3C	Multi-Family Dwellings: 5 - 9 units
6	RES3D	Multi-Family Dwellings: 10 – 19 units
7	RES3E	Multi-Family Dwellings: 20 – 49 units
8	RES3F	Multi-Family Dwellings: 50+ units
9	RES4	Temporary Lodging (Hotel/Motel)
10	RES5	Institutional Dormitories (Group Housing/Jails)
11	RES6	Nursing Homes
12	COM1	Retail Trade (Stores)
13	COM2	Wholesale Trade (Warehouses)
14	COM3	Personal/Repair Services (Service Station/Shop)
15	COM4	Professional/Technical Services (Offices)
16	COM5	Banks
17	COM6	Hospital
18	COM7	Medical Office/Clinics
19	COM8	Entertainment & Recreation (Restaurants/Bars)
20	COM9	Theaters
21	COM10	Parking (Garages)
22	IND1	Heavy Industrial
23	IND2	Light Industrial
24	IND3	Food/Drugs/ Chemicals
25	IND4	Metals/Mineral Processing
26	IND5	High Technology
27	IND6	Construction (Offices)
28	AGR1	Agriculture
29	REL1	Church/Non-Profit
30	GOV1	Government General Services (Office)
31	GOV2	Government Emergency Response (Police/Fire/EOC)
32	EDU1	Grade Schools
33	EDU2	Colleges/Universities

2.4.2 Occupancy Mapping

Occupancy mapping tables indicate, by occupancy, the percent distribution of square footage among various structural or model building types (see Table 2.5 for a complete list of model building types available within HAZUS®MH MR-1). Occupancy mapping

relationships within HAZUS®MH MR-1 exist at two levels: 1) general mapping schemes, which indicate the distribution of square footage across the five basic construction classes or basic building types (Wood, Concrete, Steel, Masonry, and Manufactured Housing), and 2) specific occupancy mapping schemes or building type distributions, which indicate, for a given occupancy and material type, the distribution across the detailed model building types, including variations reflecting the various design levels ("L" = low-, "M"= moderate- and "H" = high-seismic design) and building quality classes ("C" = code, "I" = inferior, and "S" = superior).

Table 2.5. HAZUS®MH Model Building Types (after DHS/FEMA, 2005)

HAZUS®MH Model Building Type	Description
W1	Wood, light frame (≤ 5,000 square feet)
W2	Wood, commercial and industrial (>5,000 square feet)
S1L, S1M, S1H	Steel moment frame, low-, mid- and high-rise
S2L, S2M, S2H	Steel braced frame, low-, mid- and high-rise
S3	Steel light frame
S4L, S4M, S4H	Steel frame with cast-in-place concrete shear walls, low-, mid- and high-rise
S5L, S5M, S5H	Steel frame with unreinforced masonry infill walls, low-, mid- and high-rise
C1L, C1M, C1H	Concrete moment frame, low-, mid- and high-rise
C2L, C2M, C2H	Concrete shear walls, low-, mid- and high-rise
C3L, C3M, C3H	Concrete frame with unreinforced masonry infill walls, low-, mid- and high-rise
PC1	Pre-cast concrete tilt-up walls
PC2L, PC2M, PC2H	Pre-cast concrete frames with concrete shear walls, low-, mid- and high-rise
RM1L, RM1M	Reinforced masonry bearing walls with wood or metal deck diaphragms, low- and mid-rise
RM2L, RM2M, RM2H	Reinforced masonry bearing walls with pre-cast concrete diaphragms, low-, mid- and high-rise
URML, URMM	Unreinforced masonry bearing walls, low- and mid-rise
MH	Mobile homes

The occupancy mapping data tables are accessible through the HAZUS®MH MR-1 "Inventory", "General Building Stock", "Occupancy Mapping" menu selections. Select a mapping scheme from the list, right click for the context menu, and select "View…" to review the general "Mapping Scheme" which provides, for each occupancy, the percent distribution across the five general building type categories (Wood, Concrete, Steel, Masonry, and Manufactured Housing).

To view the more detailed specific occupancy mapping scheme or "building type distribution", right click on any of the cells in the general mapping scheme and select

"View Current Building Type Distribution…". This will bring up a table with columns for each of the detailed model building types, and rows for each design level/building quality combination. In essence, the occupancy-mapping schemes consider multiple versions of the model building types distinguished by the various seismic design levels and building qualities. As a result, each model building type has 9 different variations, as identified in Table 2.6.

Table 2.6. Design Level and Building Quality Combinations Used in HAZUS®MH MR-1 Mapping Schemes

Design Level	Building Quality		
	Code	**Inferior**	**Superior**
High Seismic Design	1) High-Code	4) High-Inferior	7) High-Superior
Moderate Seismic Design	2) Moderate-Code	5) Moderate-Inferior	8) Moderate-Superior
Low Seismic Design	3) Low-Code	6) Low-Inferior	9) Low-Superior

In practice, several of the combinations are often unused. For example, in California, "High – Inferior", "Moderate - Inferior", and "Moderate - Superior" are not used, and "High-Superior" is limited to three special occupancy classes (RES6/prisons, COM6/hospitals, and GOV2/EOCs). Because several of the combinations are never used, the upcoming version of HAZUS®MH, HAZUS®MH MR-2, scheduled for release in the summer of 2006, will collapse the building type categories to the seven basic classes listed in Table 2.7. This realignment of building type variations impacts a significant number of tables used by HAZUS®MH, but the HAZUS®MH developers have assured us that there will be a mechanism for importing HAZUS®MH MR-1 study regions into HAZUS®MH MR-2, so the modification should not be problematic to users.

The distributions given in these tables drive which vulnerability functions will be used to estimate damage and loss for each occupancy class. Default mapping schemes are provided with the HAZUS®MH software, which vary by region (e.g., east coast, mid-west and west coast). The basic default mapping schemes for California are designated "CA1", CA2", and "CA3". "CA3" is applied in high seismic hazards zones (6250 (89%) of census tracts in California) "CA2" is used for moderate seismic hazards zones (583 or 8% of CA census tracts), and "CA1" is used for low seismic hazard zones (216 or 3% of CA census tracts). A HAZUS®MH study region can make use of more than one mapping scheme at a time; any available mapping scheme can be assigned to any individual or group of census tracts.

Table 2.7. Revised Design Level and Building Quality Combinations Expected to be Used in HAZUS®MH MR-2 Mapping Schemes (Courtesy J. Bouabid, PBS&J)

HAZUS®MH MR-2 Designation (NEW)		HAZUS®99 & HAZUS®MH MR-1 Designation (OLD)	
Design Level	**Description**	**Building Quality**	**Design Level**
HC	High - Code	Code	High
MC	Moderate – Code	Code	Moderate
LC	Low – Code	Code	Low
HS	Special High - Code	Superior	High
MS	Special Moderate – Code	Superior	Moderate
LS	Special Low-Code	Superior	Low
<removed>		Inferior	High
<removed>		Inferior	Moderate
PC	Pre-Code	Inferior	Low

2.4.3 General Building Stock Square Footage Factors

Table 2.8 provides the assumed building size for each occupancy class, and was utilized for the original derivation of default building count tables provided with the HAZUS®MH MR-1 software. While this table is stored in the HAZUS®MH MR-1 SQL Server database, it is not accessible through the HAZUS®MH menus because tables which are derived from it have been pre-calculated nationwide, and are delivered with the software. However, the data is provided in the Technical Manual as part of Table 3.6 "Default Full Replacement Cost Models (Means, 2002)" within the column titled "Means Model Description (Means Model Number)". For convenience, the complete table is presented here as Table 2.9. It should be noted that the assumed typical building size has changed significantly from HAZUS®99, as the underlying Means models (R.S. Means Square Foot Costs, 2002) used to estimate replacement cost have changed.

2.4.4 Building Count

The Building Count tables, accessible through the "Inventory", "General Building Stock", "Building Count" menu selections, provide an estimate of the number of buildings in each census tract by:

- Specific occupancy (see Table 2.4 for the list of occupancy types)
- General occupancy (Residential, Commercial, Industrial, Agriculture, Religion, Government, Education, and Total)
- Specific model building type (see Table 2.5 for the list of model building types)

Table 2.8. HAZUS®MH MR-1 Default Building Size Assumptions (DHS/FEMA, 2005)

Occupancy Class Number	HAZUS®MH Occupancy Class	HAZUS®MH MR-1 Default Building Size (Square Feet)
1	RES1	1,600
2	RES2	1,063
3	RES3A	3,000
4	RES3B	3,000
5	RES3C	8,000
6	RES3D	12,000
7	RES3E	40,000
8	RES3F	60,000
9	RES4	135,000
10	RES5	25,000
11	RES6	25,000
12	COM1	110,000
13	COM2	30,000
14	COM3	10,000
15	COM4	80,000
16	COM5	4,100
17	COM6	55,000
18	COM7	7,000
19	COM8	5,000
20	COM9	12,000
21	COM10	145,000
22	IND1	30,000
23	IND2	30,000
24	IND3	45,000
25	IND4	45,000
26	IND5	45,000
27	IND6	30,000
28	AGR1	30,000
29	REL1	17,000
30	GOV1	11,000
31	GOV2	11,000
32	EDU1	130,000
33	EDU2	50,000

In the HAZUS®MH MR-1 default data provided with the software, the building counts were derived from the "Square Footage Distribution by Occupancy and Census Tract" for occupancy counts, and from the square footage tables and mapping schemes for the building type counts. Both derivations made use of the "General Building Stock Square Footage Factor" table, relating occupancy to typical building size. The building count

data is used by HAZUS®MH to develop summaries of building damage counts by damage state.

2.4.5 Replacement Cost Model Data

Building replacement cost models –a typical cost per square foot for a given occupancy - are used to estimate total value of the exposed inventory. Replacement costs used in HAZUS®MH MR-1 are based on industry standard national average models contained in the 2002 edition of "Means Square Foot Costs" (R.S. Means, 2002). HAZUS®MH MR-2 will include an update to 2005 costs based on Means (R.S. Means, 2005). The basic replacement cost models are provided here for MR-1 and MR-2, in Table 2.9, and 2.10, respectively. Because the HAZUS®MH MR-1 (and MR-2) default exposure value data are provided with the software, the underlying replacement cost models stored within SQL Server are not accessible to the user through the HAZUS®MH MR-1 user interface.

It should be noted that the HAZUS®MH replacement cost model for single family homes (RES1) is based on a complex algorithm related to geographic region, per capita income at the census block level, and the presence of basements. Accordingly, it is not possible to tabulate a single value representative of replacement costs nationwide. Readers interested in the details of the model are encouraged to read Chapter 3 of the HAZUS®MH MR-1 Technical Manual.

The final component of the building replacement cost model is the regional cost modifier that modifies the national average replacement cost models to reflect local conditions. The cost modifiers, based on Means "location factors", are tabulated within HAZUS®MH. A single cost modifier for all construction types, summarized at the county level, was utilized in MR-1. MR-2 will utilize two local modifiers: one for residential construction, and one for all other (non-residential) construction, also assessed at the county level. Location Factors used in MR-1 and MR-2 are provided in Table 2.11.

In addition to building replacement costs, HAZUS®MH also estimates the value of building contents, using a contents value model by specific occupancy, expressed as a percent of building replacement value. That is, for a given occupancy, the value of building contents is estimated from the total building replacement value. For example, for single family homes, contents are assumed to be 50% of the value of the building itself. The contents replacement value model used in HAZUS®MH MR-1 (and MR-2) is identical to the model used in HAZUS®99, and is provided in Table 2.12.

Table 2.9. HAZUS®MH MR-1 (2002) Replacement Cost Model (DHS/FEMA, 2005)

OCC Class #	OCC Code	OCC Description	Means Model Description	Means Cost 2002
1	RES1	Single Family Dwelling	<multiple models>	
2	RES2	Manufactured Housing	75% @ 850 SF (Single Wide)	$61.47
3	RES3A	Multi Family Dwelling – small: duplex	SFR Avg 2 St., MF adj, 3000 SF	$68.27
4	RES3B	Multi Family Dwelling – small: triplex/quad	SFR Avg 2 St., MF adj, 3000 SF	$73.70
5	RES3C	Multi Family Dwelling – medium: 5-9 units	Apt, 1-3 st, 8,000 SF (M.010)	$114.73
6	RES3D	Multi Family Dwelling – medium: 10-19 units	Apt., 1-3 st., 12,000 SF (M.010)	$103.81
7	RES3E	Multi Family Dwelling – large: 20-49 units	Apt., 4-7 st., 40,000 SF (M.020)	$101.87
8	RES3F	Multi Family Dwelling – large: 50+ units	Apt., 4-7 st., 60,000 SF (M.020)	$99.65
9	RES4	Temp. Lodging	Hotel, 4-7 st., 135,000 SF (M.350)	$100.37
10	RES5	Institutional Dormitory	College Dorm, 2-3 st, 40,000 SF (M.130)	$96.79
11	RES6	Nursing Home	Nursing Home, 2 st., 25,000 SF (M.450)	$94.90
12	COM1	Retail Trade	Store, Dept., 1 st., 110,000 SF (M.610)	$58.64
13	COM2	Wholesale Trade	Warehouse, 30,000 SF (M.690)	$57.34
14	COM3	Personal and Repair Services	Garage, Repair, 4,000 SF (M.290)	$89.54
15	COM4	Prof./ Tech./Business Services	Office, 5-10 st., 100,000 SF (M.470)	$88.28
16	COM5	Banks	Bank, 1 st., 4100 SF (M.050)	$147.15
17	COM6	Hospital	Hospital, 2-3 st., 55,000 SF (M.330)	$137.66
18	COM7	Medical Office/Clinic	Medical office, 2 st., 7,000 SF (M.410)	$120.29
19	COM8	Entertainment & Recreation	Restaurant, 1 st., 5,000 SF (M.530)	$125.28
20	COM9	Theaters	Movie Theatre, 12,000 SF (M.440)	$95.25
21	COM10	Parking	Garage, Pkg, 5 st., 145,000 SF (M.270)	$32.57
22	IND1	Heavy	Factory, 1 st., 30,000 SF (M.200)	$67.76
23	IND2	Light	Warehouse, 30,000 SF (M.690)	$57.34
24	IND3	Food/Drugs/Chemicals	College Lab, 1 st., 45,000 SF (M.150)	$115.14
25	IND4	Metals/Minerals Processing	College Lab, 1 st., 45,000 SF (M.150)	$115.14

OCC Class #	OCC Code	OCC Description	Means Model Description	Means Cost 2002
26	IND5	High Technology	College Lab, 1 st., 45,000 SF (M.150)	$115.14
27	IND6	Construction	Warehouse, 30,000 SF (M.690)	$57.34
28	AGR1	Agriculture	Church, 1 st., 17,000 SF (M.090)	$108.08
29	REL1	Church	Warehouse, 30,000 SF (M.690)	$57.34
30	GOV1	General Services	Town Hall, 1 st., 11,000 SF (M.670)	$86.47
31	GOV2	Emergency Response	Police Station, 2 st., 11,000 SF (M.490)	$129.07
32	EDU1	Schools/Libraries	School, High, 130,000 SF (M.570)	$86.28
33	EDU2	Colleges/Universities	College Class. 2-3 st, 90,000 SF (M.120)	$95.49

Table 2.10. HAZUS®MH MR-2 Replacement Cost Model (ABS Consulting, 2005)

OCC Class #	OCC Code	OCC Description	Means Model Description	Means Cost 2005
1	RES1	Single Family Dwelling	<multiple models>	
2	RES2	Manufactured Housing	Manufactured Housing Institute, 2002 cost for new manufactured home (latest data available)	$32.16
3	RES3A	Multi Family Dwelling – small: duplex	SFR Avg 2 St., MF adj, 3000 SF	$74.91
4	RES3B	Multi Family Dwelling – small: triplex/quad	SFR Avg 2 St., MF adj, 3000 SF	$81.65
5	RES3C	Multi Family Dwelling – medium: 5-9 units	Apt, 1-3 st, 8,000 SF (M.010)	$141.48
6	RES3D	Multi Family Dwelling – medium: 10-19 units	Apt., 1-3 st., 12,000 SF (M.010)	$126.65
7	RES3E	Multi Family Dwelling – large: 20-49 units	Apt., 4-7 st., 40,000 SF (M.020)	$124.63
8	RES3F	Multi Family Dwelling – large: 50+ units	Apt., 4-7 st., 60,000 SF (M.020)	$121.44
9	RES4	Temp. Lodging	Hotel, 4-7 st., 135,000 SF(M.350)	$120.45
10	RES5	Institutional Dormitory	College Dorm, 2-3 st, 25,000 SF (M.130)	$137.69
11	RES6	Nursing Home	Nursing Home, 2 st., 25,000 SF (M.450)	$118.71
12	COM1	Retail Trade	Store, Dept., 1 st., 110,000 SF (M.610)	$77.85
13	COM2	Wholesale Trade	Warehouse, 30,000 SF (M.690)	$70.48
14	COM3	Personal and Repair Services	Garage, Repair, 10,000 SF (M.290)	$96.32
15	COM4	Prof./ Tech./Business Services	Office, 5-10 st., 80,000 SF (M.470)	$117.53
16	COM5	Banks	Bank, 1 st., 4100 SF (M.050)	$170.00
17	COM6	Hospital	Hospital, 2-3 st., 55,000 SF (M.330)	$206.33
18	COM7	Medical Office/Clinic	Medical office, 2 st., 7,000 SF (M.410)	$150.78
19	COM8	Entertainment & Recreation	Restaurant, 1 st., 5,000 SF (M.530)	$162.79
20	COM9	Theaters	Movie Theatre, 12,000 SF (M.440)	$114.33
21	COM10	Parking	Garage, Pkg, 5 st., 145,000 SF (M.270)	$40.32
22	IND1	Heavy	Factory, 1 st., 30,000 SF (M.200)	$82.18
23	IND2	Light	Warehouse, 30,000 SF (M.690)	$70.48
24	IND3	Food/Drugs/Chemicals	College Lab, 1 st., 45,000 SF (M.150)	$135.09

OCC Class #	OCC Code	OCC Description	Means Model Description	Means Cost 2005
25	IND4	Metals/Minerals Processing	College Lab, 1 st., 45,000 SF (M.150)	$135.09
26	IND5	High Technology	College Lab, 1 st., 45,000 SF (M.150)	$135.09
27	IND6	Construction	Warehouse, 30,000 SF (M.690)	$70.48
28	AGR1	Agriculture	Warehouse, 30,000 SF (M.690)	$70.48
29	REL1	Church	Church, 1 st., 17,000 SF (M.090)	$129.09
30	GOV1	General Services	Town Hall, 1 st., 11,000 SF (M.670)	$99.48
31	GOV2	Emergency Response	Police Station, 2 st., 11,000 SF (M.490)	$152.83
32	EDU1	Schools/Libraries	School, High, 130,000 SF (M.570)	$107.53
33	EDU2	Colleges/Universities	College Class. 2-3 st, 50,000 SF (M.120)	$132.62

Table 2.11. HAZUS®MH MR-1 and MR-2 Means-based Location Factors for California

County FIPS Code	County Name	HAZUS®MH MR-1 Means-based (2002) Adjustment Factor: All Construction	HAZUS®MH MR-2 Means-based (2005) Adjustment Factor: Residential	HAZUS®MH MR-2 Means-based (2005) Adjustment Factor: Non-Residential
06001	Alameda	1.18	1.14	1.13
06003	Alpine	1.00	1.09	1.08
06005	Amador	1.00	1.10	1.09
06007	Butte	1.10	1.10	1.09
06009	Calaveras	1.00	1.09	1.08
06011	Colusa	1.00	1.12	1.10
06013	Contra Costa	1.16	1.15	1.12
06015	Del Norte	1.00	1.09	1.05
06017	El Dorado	1.00	1.11	1.10
06019	Fresno	1.10	1.09	1.07
06021	Glenn	1.00	1.12	1.11
06023	Humboldt	1.00	1.09	1.06
06025	Imperial	1.00	0.94	0.95
06027	Inyo	1.00	1.03	1.03
06029	Kern	1.09	1.05	1.04
06031	Kings	1.00	1.08	1.07
06033	Lake	1.00	1.12	1.11
06035	Lassen	1.00	1.06	1.05
06037	Los Angeles	1.09	1.05	1.05
06039	Madera	1.00	1.08	1.06
06041	Marin	1.23	1.20	1.16
06043	Mariposa	1.00	1.09	1.08
06045	Mendocino	1.00	1.12	1.09
06047	Merced	1.11	1.09	1.08
06049	Modoc	1.00	1.06	1.04
06051	Mono	1.00	1.05	1.04
06053	Monterey	1.15	1.09	1.08
06055	Napa	1.00	1.13	1.11
06057	Nevada	1.00	1.06	1.05
06059	Orange	1.09	1.04	1.04
06061	Placer	1.11	1.09	1.08
06063	Plumas	1.00	1.10	1.09
06065	Riverside	1.09	1.03	1.02
06067	Sacramento	1.11	1.11	1.10
06069	San Benito	1.00	1.09	1.08
06071	San Bernardino	1.08	0.99	0.99
06073	San Diego	1.09	1.04	1.04
06075	San Francisco	1.23	1.21	1.22
06077	San Joaquin	1.11	1.10	1.09
06079	San Luis Obispo	1.11	1.08	1.06

County FIPS Code	County Name	HAZUS®MH MR-1 Means-based (2002) Adjustment Factor: All Construction	HAZUS®MH MR-2 Means-based (2005) Adjustment Factor: Residential	HAZUS®MH MR-2 Means-based (2005) Adjustment Factor: Non-Residential
06081	San Mateo	1.23	1.19	1.18
06083	Santa Barbara	1.11	1.06	1.05
06085	Santa Clara	1.23	1.14	1.13
06087	Santa Cruz	1.15	1.18	1.18
06089	Shasta	1.00	1.10	1.08
06091	Sierra	1.00	1.08	1.06
06093	Siskiyou	1.00	1.07	1.06
06095	Solano	1.13	1.13	1.11
06097	Sonoma	1.23	1.16	1.13
06099	Stanislaus	1.11	1.12	1.11
06101	Sutter	1.00	1.11	1.10
06103	Tehama	1.00	1.11	1.10
06105	Trinity	1.00	1.10	1.07
06107	Tulare	1.10	1.06	1.05
06109	Tuolumne	1.00	1.08	1.06
06111	Ventura	1.11	1.06	1.06
06113	Yolo	1.00	1.12	1.10
06115	Yuba	1.00	1.11	1.10

Table 2.12. HAZUS®MH MR-1 (& MR-2) Contents Value Model

Occupancy Class Number	HAZUS®MH Occupancy Class	HAZUS®MH Contents Value Model (Expressed as a Percent of Structure Value)
1	RES1	50%
2	RES2	50%
3	RES3A	50%
4	RES3B	50%
5	RES3C	50%
6	RES3D	50%
7	RES3E	50%
8	RES3F	50%
9	RES4	50%
10	RES5	50%
11	RES6	50%
12	COM1	100%
13	COM2	100%
14	COM3	100%
15	COM4	100%
16	COM5	100%
17	COM6	150%
18	COM7	150%
19	COM8	100%
20	COM9	100%
21	COM10	50%
22	IND1	150%
23	IND2	150%
24	IND3	150%
25	IND4	150%
26	IND5	150%
27	IND6	100%
28	AGR1	100%
29	REL1	100%
30	GOV1	100%
31	GOV2	150%
32	EDU1	100%
33	EDU2	150%

2.4.6 Dollar Exposure

These data tables are accessible through the "Inventory", "General Building Stock", "Dollar Exposure" menu selections. These databases tabulate total replacement costs or dollar exposure (in thousands of dollars) associated with the general building stock by census tract and:

- specific occupancy (Buildings, Contents, and Total)
- general occupancy (Buildings, Contents, and Total)
- specific model building type (Buildings, Contents, and Total)

In the default data delivered with the software, these data have been derived from replacement cost models ($/square foot), location factors, and census tract – square footage occupancy tables for the summaries of building exposure by occupancy, and also required mapping scheme data to arrive at building exposure values by model building type. Contents value tables are derived from contents value models and building exposure values by occupancy.

3. Prioritizing Data Collection Efforts

3.1 Prioritization Process

The various building and lifeline components analyzed by HAZUS®MH vary in terms of the quality of the default data and in the magnitude of their contribution to the total loss. For example, railway tracks are unlikely to contribute significantly to the losses for most HAZUS®MH scenarios, and as such, the default data from the Bureau of Transportation Statistics are suitable for these purposes. On the other hand, clusters of high-rise buildings in downtown areas, whose height are not adequately reflected in the default building stock, can suffer significant losses depending on the event. An update to this type of default data might be more productive in theory, although in practical terms the update process can be difficult.

Given the various levels of database complexity, data detail, and applicability to loss estimation, determining which parameters and databases to adjust may present a significant challenge to the user. Accordingly, this guideline includes a prioritization scheme to facilitate the selection of HAZUS®MH databases for modification, given the user's interest and available resources. The criteria employed for prioritization comprise: level of effort to update, quality of default data, and contribution to economic loss (rather than emergency response requirements).

In this *Phase Two* guide, the prioritization schemes presented in the *Phase One* guidelines are updated based on the quality of the default data in HAZUS®MH and the contribution to total loss. Much of the default data in HAZUS®MH have been updated or removed due to homeland security concerns, requiring that the default data be reassessed. Additionally, the underlying data structure in HAZUS®MH is significantly more complex than HAZUS®99, requiring that the level of effort to update data be reassessed. All of these factors required a reassessment of the prioritization scheme.

The following sections summarize the prioritization process. It provides an updated prioritization table for lifelines and transportation databases for HAZUS®MH (Table 3.2). In addition, it provides updated priorities for general building stock (Section 3.3). Priority rating tables are provided as a guide. However, the user is encouraged to adjust the various ratings based on exposure and data availability in their study region.

3.2 Priority Ratings for Lifeline Data Updates

Within HAZUS®MH, 31 types of transportation and utility facilities are classified as "lifelines". Figure 3.1 summarizes the approach used to determine whether the associated lifeline data should be updated. Here, prioritizing data collection efforts is assumed to depend on three essential factors:

1. Is the given component a primary contributor to economic losses? Does the component's performance significantly impact network performance?

2. Is the default HAZUS®MH database complete and comprehensive?

3. Are there better data (more precise and/or robust) readily available for the user's study region area?

These elements must be considered together when assessing update priority. In general terms, if a given lifeline component is important, yet accompanying data are not available, its absence from HAZUS®MH may be due to homeland security concerns. In this situation, the user should carefully consider their needs before expending significant resources to collect the data. Similarly, if the facility data can be downloaded and processed quickly but the HAZUS®MH default data is reasonably accurate, depending on the contribution to loss, it may not be worth updating.

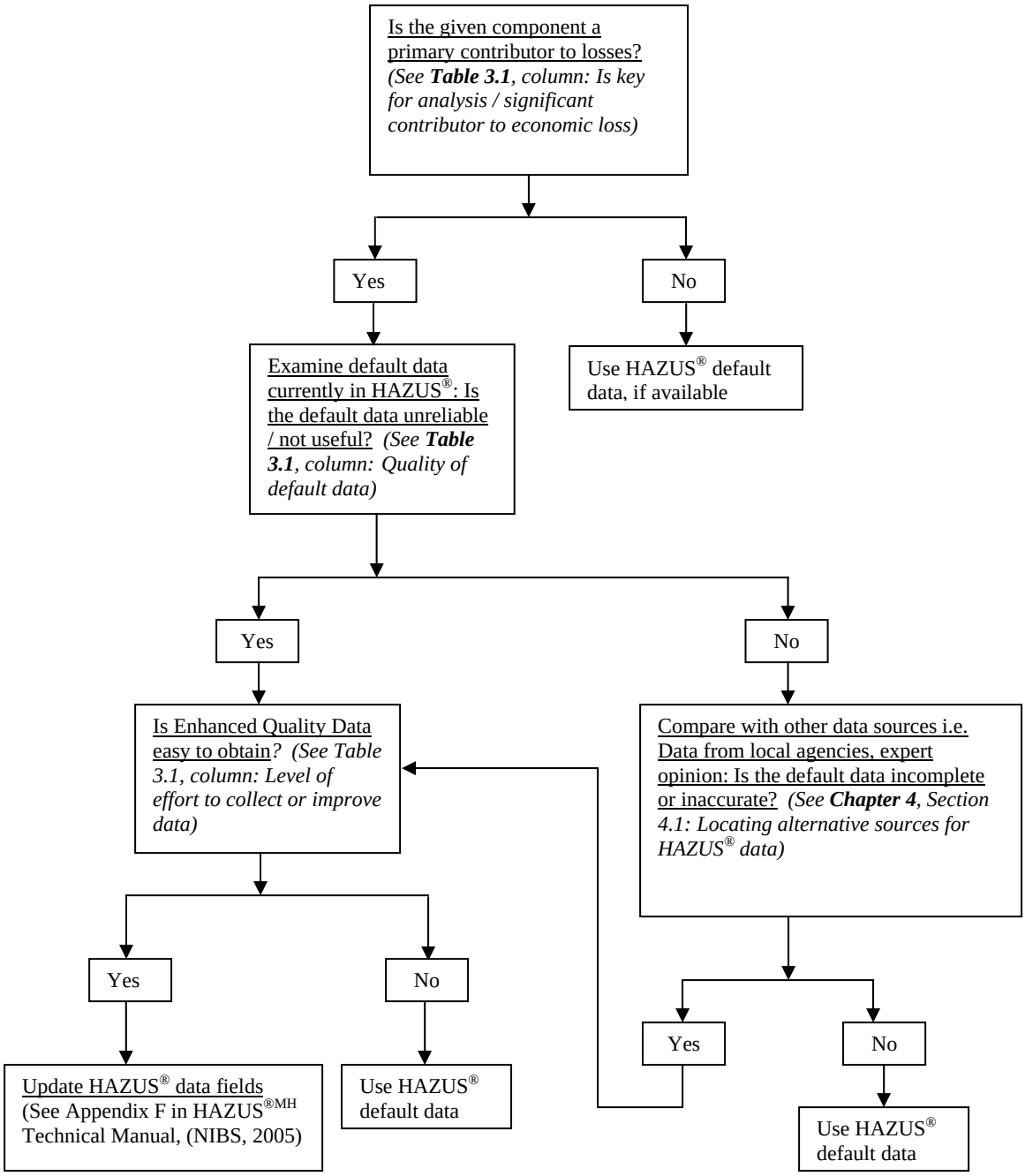


Figure 3.1. Decision Tree for Lifeline Data Collection

The specific lifelines classification scheme is presented in Table 3.2. Column 2 identifies the respective lifeline system components (e.g., the highway transportation system is made up three components; roadway segments, bridges and tunnels), each of which corresponds with a specific database table (See Appendix A). For some system components, there are a number of possible facility types (listed in column 3). For

example, the "railway facilities" component of the rail transportation system includes four types of railway facilities; urban stations, fuel facilities, dispatch facilities, and maintenance facilities. Consider the update priority for some selected lifeline components:

- Electric power substations are a significant contributor to economic loss. Data on voltage, a key parameter for classifying substations and assessing their seismic vulnerability, may be difficult to obtain, but is considered essential for accurately modeling earthquake losses.

- Railroad facility information is difficult to collect, and damage to these facilities represents a small portion of the total losses (with the possible exception of rail facilities serving major ports). Under most circumstances, less effort should be expended to collect enhanced data for railroad facilities.

- Highway bridge data in HAZUS®MH is derived from the National Bridge Inventory, and is very complete. Updating the highway bridge table with additional enhanced data is likely to have a minimal effect on total loss estimates, and as such is unlikely to require supplementary data collection.

- Performance of potable water storage tanks can have a significant impact on the availability of water supply after an earthquake. Tank data may be available from local water utilities, although homeland security concerns may be an issue.

In some circumstances, the user will wish to review the various data associated with each component and facility to determine if there is a specific attribute of the data that needs to be updated. In this instance, the user should modify the individual factor ratings to arrive at a customized prioritization scheme applicable to their study region and interests. For example, HAZUS®MH may include an acceptable representation of the airport runways in the user's study region, but associated loss estimates appear extremely high because the underlying replacement cost data overestimates the value of the runways, and needs to be modified.

Finally, for a given region a user may have collected, for example, two databases of police stations, and must merge them with the default HAZUS®MH data. In this case, the user will want to map and graph the key attribute field to assess data completeness.

Based on the project team's knowledge of the HAZUS®MH software and default data, together with their professional loss estimation experience, baseline priority ratings (high, medium or low) have been established for each of the system components (see Table 3.2) according to the 3 essential factors listed at the beginning of this section. Definitions for the rating schemes are as follows:

Factor 1: Is the given component a primary contributor to economic losses? Does the component's performance significantly impact network performance?

High – Damage to these components and facilities could result in large economic losses and/or system disruption.

Medium – Losses are calculated, but not a major contributor.

Low – Losses are not calculated within HAZUS®MH, or are considered insignificant.

Factor 2: Is the default HAZUS®MH database complete and comprehensive?

High – Default data are based on detailed national (or state) databases tracking the specific utility or transportation feature.

Medium – Default data are derived from large scale or national databases. Geographic accuracy may be less than ideal, but overall the data is considered suitable for a Level 1 analysis.

Low – Features sparse or non-existent. Little or no attribute data. Many facilities may be misplaced.

Factor 3: If better data are available, what is the level of effort required to collect it and format it for use in HAZUS®MH? (Are there better data readily available for California? If so, in what format?)

High – Data not generally collected in GIS format, or is hard to obtain for reasons of homeland security.

Medium – Data can be collected in GIS or CAD format, but one or more local agencies may need to be contacted. Attribute data may need to be collected through discussions with local agency personnel or engineers.

Low – Data available at the state level through State or Federal agencies in a format suitable for HAZUS®MH.

Together, these 3 ratings determine the overall priority for supplemental data collection. Table 3.1 provides a key indicating how the various combinations of individual factor ratings were combined. (Note: overall ratings are provided only for those combinations of rating factors that occur in prioritization tables). Table 3.2 presents final ratings for the prioritization process.

Table 3.1. Key to Assigned Overall Priority

Is key for analysis/ Significant contributor to economic loss	Quality of default data	Level of effort to collect or improve data	Overall Priority
L	M	H	LOW
L	L	H	LOW
L	L	M	LOW
L	M	M	LOW
H	H	H	LOW
M	M	H	LOW
M	L	H	LOW
M	L	M	MEDIUM
M	M	M	MEDIUM
H	L	M	HIGH
H	L	H	HIGH

Note: L= Low, M= Medium, H= High

The final combined priority ratings may be defined as follows:

Overall Update Priority Rating

High – Facility or component is a key contributor to total economic losses, default data is of low quality, and the level of effort to collect the data is medium or high.

Medium **–** Facility or component is a medium contributor to total economic losses, default data is of low or medium quality, and level of effort to collect the data is medium.

Low – Facility or component may be a low, medium, or high contributor to economic losses. Overall priority is determined as follows:

- All components considered to be "low" contributors to economic loss are considered to have "low" overall update priority, regardless of the other factor ratings.
- Components with high quality default data and high level of effort to improve upon that data are assigned a "low" overall update priority.
- Moderate contributors to loss with high level of effort required to improve the data are given a "low" overall update priority.

Table 3.2. Update Prioritization Table for Lifelines and Transportation Databases

Item No.	System Components	Facility Types	Is key for analysis/ significant contributor to economic loss	Quality of default data	Level of effort to collect or improve data	Overall Priority[1]
1	Highway Segments		Low	Medium	High	LOW
2	Highway Bridges		High	High	High	LOW
3	Highway Tunnels		Low	Low	High	LOW
4	Railway Track Segments		Low	Medium	High	LOW
5	Railway Bridges		Medium	Medium	High	LOW
6	Railway Tunnels		Low	Low	High	LOW
7	Railway Facilities	*Rail Urban Station*	Low	Low	Medium	LOW
		Rail Fuel Facility	Low	Low	Medium	LOW
		Rail Dispatch Facility	Low	Low	Medium	LOW
		Rail Maintenance Facility	Low	Low	Medium	LOW
8	Light Rail Track Segments		Low	Medium	High	LOW
9	Light Rail Bridges		Medium	Medium	High	LOW
10	Light Rail Tunnels		Low	Low	High	LOW
11	Light Rail Facilities	*DC Substation*	Low	Low	Medium	LOW
		Light Rail Dispatch Facility	Low	Low	Medium	LOW
		Light Rail Maintenance Facility	Low	Low	Medium	LOW
12	Bus Facilities	*Bus Urban Station*	Low	Medium	Medium	LOW
		Bus Fuel Facility	Low	Medium	Medium	LOW
		Bus Dispatch Facility	Low	Medium	Medium	LOW
		Bus Maintenance Facility	Low	Medium	Medium	LOW

[1] Overall Priority Determination Criteria: H= High, M= Medium, L= Low. L, M, H = Low; L,L,H = Low; L,L,M = Low; L,M,M = Low ; M,M,H = Low; M,L,H = Low; M,L,M = Medium; M,M,M = Medium; H,H,H = Low; H,L,M = High; H,L,H = High; H,M,H = Medium; H,M,M = Medium.

Table 3.2. Update Prioritization Table for Lifelines and Transportation Databases (continued)

Item No.	System Components	Facility Types	Is key for analysis/ significant contributor to economic loss	Quality of default data	Level of effort to collect or improve data	Overall Priority[1]
13	Ports and Harbors Facilities	*Waterfront Structures*	High	Medium	Medium	MEDIUM
		Cranes/Cargo handling equipment	High	Medium	Medium	MEDIUM
		Fuel Facility	Low	Medium	Medium	LOW
		Warehouses	Low	Medium	Medium	LOW
14	Ferry Facilities	*Waterfront Structures*	Medium	Low	Medium	MEDIUM
		Passenger terminals	Low	Low	Medium	LOW
		Dispatch facility	Low	Low	Medium	LOW
		Fuel facility	Low	Low	Medium	LOW
		Maintenance facilities	Low	Low	Medium	LOW
15	Airports Facilities	*Control Towers*	Low	Low	Medium	LOW
		Terminal Buildings	Low	Low	Medium	LOW
		Parking Structure	Low	Low	Medium	LOW
		Fuel facility	Low	Low	Medium	LOW
		Maintenance & Hanger facilities	Low	Low	Medium	LOW
		Airport-General	Low	Low	Medium	LOW
		Heliport Facilities	Low	Low	Medium	LOW
		Seaport/ Stolport/Gliderport	Low	Low	Medium	LOW
16	Airports Runways		Medium	Medium	Medium	MEDIUM[2]

[1] Overall Priority Determination Criteria: H= High, M= Medium, L= Low. L, M, H = Low; L,L,H = Low; L,L,M = Low; L,M,M = Low ; M,M,H = Low; M,L,H = Low; M,L,M = Medium; M,M,M = Medium; H,H,H = Low; H,L,M = High; H,L,H = High; H,M,H = Medium; H,M,M = Medium.
[2] It should be noted that for airport runways, loss estimates within HAZUS®MH are based solely on liquefaction-related damage. It is highly recommended that users concerned with runway damage collect and input liquefaction susceptibility data.

Table 3.2. Update Prioritization Table for Lifelines and Transportation Databases (continued)

Item No.	System Components	Facility Types	Is key for analysis/ significant contributor to economic loss	Quality of default data	Level of effort to collect or improve data	Overall Priority[1]
17	Potable Water Pipeline Segments		Medium	Low	High	LOW
18	Potable Water Distribution Lines		Low	Medium	Medium	LOW
19	Potable Water Facilities	*Water Treatment Plants*	High	Low	Medium	HIGH
		Wells	Low	Low	Medium	LOW
		Pump Stations	Medium	Low	Medium	MEDIUM
		Storage Tanks	High	Low	Medium	HIGH
		Control Vault/Control Station	Low	Low	Medium	LOW
20	Wastewater Pipeline Segments		Low	Low	High	LOW
21	Wastewater Distribution Lines		Low	Medium	Medium	LOW
22	Wastewater Facilities	*Wastewater Treatment Plants*	Medium	Low	Medium	MEDIUM
		Lift Stations	Medium	Low	Medium	MEDIUM
		Control Vault/Control Station	Low	Low	Medium	LOW
23	Oil Pipelines Segments		Medium	Low	High	LOW
24	Oil Systems Facilities	*Refineries*	Medium	Low	Medium	MEDIUM
		Pumping Plants	Medium	Low	Medium	MEDIUM
		Tank Farms	High	Low	Medium	HIGH
		Control Vault/Control Station	Low	Low	Medium	LOW

[1] Overall Priority Determination Criteria: H= High, M= Medium, L= Low. L, M, H = Low; L,L,H = Low; L,L,M = Low; L,M,M = Low ; M,M,H = Low; M,L,H = Low; M,L,M = Medium; M,M,M = Medium; H,H,H = Low; H,L,M = High; H,L,H = High; H,M,H = Medium; H,M,M = Medium.

Table 3.2. Update Prioritization Table for Lifelines and Transportation Databases (continued)

Item No.	System Components	Facility Types	Is key for analysis/ significant contributor to economic loss	Quality of default data	Level of effort to collect or improve data	Overall Priority[1]
25	Natural Gas Pipelines Segments		Medium	Low	High	LOW
26	Natural Gas Distribution Lines		Low	Medium	Medium	LOW
27	Natural Gas Facilities	*Compressor Stations*	Medium	Low	Medium	MEDIUM
		Control Vault/Control Station	Low	Low	Medium	LOW
28	Electric Power Facilities	*Substations*	High	Low	High	HIGH
		Generating Facilities	Medium	Low	Medium	MEDIUM
29	Electric Power Distribution Lines		Low	Medium	Medium	LOW
30	Communication Facilities	*Central Office/ Switching Stations*	High	Low	High	HIGH
		Radio/ TV Station	Low	Low	Medium	LOW
		Weather Station	Low	Low	Medium	LOW
		Other Communication Facility	Low	Low	Medium	LOW
31	Communication Distribution Cables		Low	Low	Medium	LOW

[1] Overall Priority Determination Criteria: H= High, M= Medium, L= Low. L, M, H = Low; L,L,H = Low; L,L,M = Low; L,M,M = Low ; M,M,H = Low; M,L,H = Low; M,L,M = Medium; M,M,M = Medium; H,H,H = Low; H,L,M = High; H,L,H = High; H,M,H = Medium; H,M,M = Medium.

3.3 Priority Ratings for Building Inventory Data Updates

As discussed in Section 2.4, there are nine different kinds of HAZUS®MH data tables storing inventory and cost parameter data for the general building stock in the SQL server database. These data tables include:

- Square footage occupancy data by census tract
- General occupancy mapping data – distribution, by occupancy, of construction across basic construction categories (wood, concrete, steel, masonry, and manufactured housing)
- Specific occupancy mapping data - distribution, by occupancy, of construction within each basic construction category for each available mapping scheme
- Square footage factors
- Building count occupancy data by census tract
- Building replacement cost model tables
- Local cost modifier table
- Contents value model table
- Building exposure occupancy data by census tract

Although these data tables are available to the user for modification through the HAZUS®MH Graphical User Interface (GUI), updating an entire table this way is generally not practical. The tables would also be available to the user through licensed SQL Server software. However, because the tables are "disconnected" as discussed in Section 2.4, modifying a single table without modifying all dependent tables would result in inconsistent databases and unreliable results. Accordingly, it is not recommended that the user modify inventory directly. Instead, the MaSC and BIRT tools (discussed briefly in Section 2.4, and in more detail in Appendices B and C) should be used to update various building inventory databases.

A baseline data collection prioritization has been established, using the same three criteria employed for lifeline data (see Section 3.2): (1) significance as a contributor to economic loss; (2) quality of default data; and (3) level of effort to update.

The definitions for each rating factor as applied to the general building stock are provided below, followed by an explanation of the overall rating. The individual and overall ratings are provided in Table 3.3.

Factor 1: Is the given component a primary contributor to economic losses?

High – Applies to data tables used to characterize the general building stock exposure in terms of building square footage or replacement value. These tables are the fundamental basis of the calculation of building damage and loss to buildings in the general building stock

Medium – Applies to data tables used to characterize the vulnerability of buildings, indirectly impacting the calculation of economic loss.

Low – Applies to data tables not directly used in the calculation of damage and economic losses to buildings.

Factor 2: Is the default HAZUS®MH database complete and comprehensive?

As discussed in Section 2.4, the default building inventory within HAZUS®MH is proxy data developed from Census and other commercial data. While not based on site-specific or local data, this default data was developed for applicability across the entire U.S. on a consistent basis.

High – Applies to databases developed from local data. Since the default database is proxy data, none of the default data tables are considered to be of HIGH quality.

Medium – Applies to proxy data sufficient for a Level 1 analysis, and that data with a less than current vintage (e.g., 2002 replacement cost models).

Low – Applies to "second degree" proxy data, such as building count data derived from proxy square footage exposure data and estimated typical building sizes.

Factor 3: Are there better data readily available for California? (What is the level of effort required to collect better data?)

High – Applies to any update that requires extensive geocoding or application of complex inference algorithms.

Medium – Applies to updates that require classification of various data (application of simple inference algorithms), basic database manipulation (e.g., aggregation queries), or cost breakdown calculations.

Low – Applies to updates that are simple data entry within HAZUS®MH.

Together, these 3 ratings determine the overall priority for supplemental data collection for building inventory data, the results for which are recorded in Table 3.3. The final combined priority ratings may be defined as follows:

Overall Update Priority Rating

High – High contributors to economic loss, with a “Low” or “Medium” level of effort to complete. This rating is also assigned to “Medium” contributors to loss with a “Low” level of effort to complete.

Medium – “High” contributors to economic loss, with a “High” level of effort to complete, “Medium” contributors to economic loss with a “Medium” level of effort to complete, and “Low” contributors to economic loss with a “Low” level of effort to complete.

Low – “Medium” contributors to economic loss with a “High” level of effort to complete, and “Low” contributors to economic loss with a “Medium” level of effort to complete.

To provide the user with some guidance and strategies for updating building inventory data tables, Table 3.4 provides a list of candidate data updates for databases that recorded a HIGH and MEDIUM update priority in Table 3.3. Table 3.4 briefly describes the designated update, and lists the required input data. Chapter 5 discusses these update strategies and the required inference algorithms in more detail.

Table 3.3. Update Prioritization Table for General Building Stock Data in HAZUS®MH

GBS Data Table	Key contributor to economic losses?	Quality of Default Data	Level of Effort to collect or improve data	Overall Priority
Square footage occupancy data by census tract (see Section 2.4.1)	HIGH	MEDIUM	Variable. MEDIUM when using BIRT tool, if Assessor's database has been geocoded, or if updated from interim census data. HIGH when using BIRT tool, if Assessor's database has not been geocoded.	**HIGH** (if Assessor's database has been geocoded, or if updated from interim census data) **MEDIUM** (if Assessor's database has not been geocoded.)
General Occupancy Mapping Tables (see Section 2.4.2)	MEDIUM	MEDIUM	Variable. LOW-MEDIUM when modified from HAZUS®99 mapping scheme tables using the MaSC tool. MEDIUM-HIGH when modified using BIRT tool with Assessor's data.	**MEDIUM**.
Specific Occupancy Mapping tables (see Section 2.4.2)	MEDIUM	MEDIUM	MEDIUM-HIGH when modified from HAZUS®99 mapping scheme tables using the MaSC tool (requires additional data or expert opinion)	**MEDIUM**.
Square footage factors (see Section 2.4.3)	LOW (impacts results provided by building count)	LOW	Variable. LOW when using BIRT tool to edit factors directly. MEDIUM when using BIRT tool with Assessor's data	**LOW**
Building count tables (see Section 2.4.4)	LOW (impacts results provided by building count)	LOW	Variable. LOW when using BIRT tool to apply edited square footage factors. MEDIUM when using BIRT tool with Assessor's data.	**MEDIUM**
Replacement cost model data (see Section 2.4.5)	HIGH	MEDIUM (MR-1 model is for 2002)	LOW when using BIRT tool.	**HIGH**
Local cost modifier table (see Section 2.4.5)	HIGH	MEDIUM (MR-1 model is for 2002)	LOW when using BIRT tool.	**HIGH**
Contents Value model data (see Section 2.4.5)	MEDIUM	MEDIUM	Low when using BIRT tool.	**HIGH**
Building dollar exposure tables (see Section 2.4.6)	HIGH	MEDIUM	LOW when using BIRT tool.	**HIGH**

Table 3.4. Candidate General Building Stock Inventory Data Updates and Data Requirements

No.	Update Strategy	Required Data	Update Prioritization
Level 1 Updates			
1A* Sect. 5.2.1	Using the BIRT, update the HAZUS replacement cost model tables (replacement cost per square foot, by occupancy)	Updated Means (or other local) building replacement cost models (all cost models contained in HAZUS®MH MR-1 are based on Means 2002, while HAZUS®MH MR-2 uses Means 2005). *The BIRT default update reflects the 2005 models contained in HAZUS®MH MR-2. The user may also change the model contained in BIRT to reflect local input or expert opinion.*	**HIGH** (if no Assessor's data is available)
1B* Sect. 5.2.1	Using the BIRT, update the Means-based Regional Cost Modifier to reflect increase in costs over time as well as locational factors.	Historical Cost Index data provided in Means "Square Foot Costs" Publication, or from other sources. *The BIRT default update reflects the 2005 models contained in HAZUS®MH MR-2. The user may also change the model contained in BIRT to reflect local input or expert opinion.*	**HIGH** (if no Assessor's data is available)
1C* Sect. 5.2.1	Using the BIRT, update the HAZUS contents value model (contents value estimated as a percent of structure value, by occupancy)	Estimated contents value expressed as a percent of structure value, by occupancy. (Note: the contents value model in HAZUS®MH MR-2 is identical to the model in HAZUS®MH MR-1). *The user may change the model contained in BIRT to reflect local input or expert opinion.*	**HIGH** whenever building replacement cost is updated.
1D* Sect. 5.2.1	Using the BIRT, update the General Building Stock Square Footage Factors used to estimate building counts from square footage data.	Estimate of typical size of building, by occupancy. May be obtained from expert opinion or from processed Assessor's data (i.e., building occupancy information, square footage data, association of Assessor's occupancy classes with HAZUS®MH occupancy classes). Typical building sizes utilized in HAZUS®MH MR-1 are based on Means 2002, while HAZUS®MH MR-2 uses Means 2005. *The BIRT default update reflects the 2005 models contained in HAZUS®MH MR-2. The user may also change the model contained in BIRT to reflect local input or expert opinion.*	**HIGH** when BIRT is used to update from MR-1 baseline (2002) to MR-2 baseline (2005), or when square footage data is updated without updating building count.

* Note: it is strongly recommended that when using BIRT to update from MR-1 baseline (2002) to MR-2 baseline (2005), that all the four Level 1 updates (Updates 1A, 1B, 1C and 1D) be completed at the same time. That is, these four updates should be done as a "suite" of updates.

Table 3.4. Candidate General Building Stock Inventory Data Updates and Data Requirements (continued)

No.	Update Strategy	Required Data	Update Prioritization
Level 2 Updates			
2 Sect. 5.2.2	Using the BIRT, update the census tract-based "Square Footage – Occupancy" table from Assessor's data.	Assessor's data on building occupancy, square footage, and census tract location for each building/parcel	**HIGH** (if Assessor's database has been geocoded and/or census tract location is known) **MEDIUM** (if Assessor's database has not been geocoded.)
3 Sect. 5.2.3	Through the HAZUS®MH GUI, update the general mapping scheme (overall percent distribution of building square footage across basic structural types – wood, concrete, steel, masonry, manufactured housing – by occupancy) from Assessor's data.	Assessor's data on building occupancy, square footage, and construction class.	**MEDIUM**
4 Sect. 5.2.4	Using the BIRT, update the census tract-based "Building Count" table from Assessor's data	Assessor's data on building occupancy, and census tract location for each building/parcel.	**MEDIUM** (if Assessor's database has been geocoded and/or census tract location is known) **LOW** (if Assessor's database has not been geocoded.)
5 Sect. 5.2.5	Using the HAZUS®MH Advanced Engineering Building Module (AEBM), analyze unreinforced masonry structures on a building-by-building basis	Inventory of URM structures, compilation of which is required by the California Seismic Safety Commission. Requires geocoding and may require additional data collection (occupancy, square footage, number of occupants)	**HIGH** (if data is geocoded, especially if general mapping scheme is updated from Assessor's data) **MEDIUM** (if not geocoded.)
6 Sect. 5.2.6	Using the MaSC, update the specific occupancy detailed mapping schemes to better reflect the distribution of building heights across the entire study region, or create a separate mapping scheme for application in downtown urban centers.	Requires data on distribution of building height by occupancy and model building type (structural type), or, data on distribution of building height by occupancy (no knowledge of distribution by model building type)	**MEDIUM**
7 Sect. 5.2.7	Using the MaSC (or through the HAZUS GUI), update the specific occupancy detailed mapping schemes to better reflect the distribution of particularly vulnerable structures (e.g., URM, NDCF, tilt-up).	Data on usage of vulnerable building types within the community (e.g., SSC inventory of URM buildings), other occupancy and construction data from Assessor's database, inference algorithms	**MEDIUM**

Table 3.4. Candidate General Building Stock Inventory Data Updates and Data Requirements (continued)

No.	Update Strategy	Required Data	Update Prioritization
Level 2 Updates (Continued)			
8 Sect. 5.2.8	Using the BIRT, update square footage distribution by census tract, based on census updates (available approx. every 4 years)	Growth ratios by census tract derived from HAZUS®MH census data and updated census data (must be within same decade, otherwise census tracts may change)	**CURRENTLY LOW** (default inventory is based on 2000 census data; priority will increase over time, as growth continues and 2000 census data becomes outdated)

4. Guidelines for Locating Alternate Data Sources and Updating Default Lifeline Data

Once the user has identified high priority data for collection, the process of locating alternate data sources and updating the default databases begins. This chapter suggests some general principles for the user to follow when searching for data (Section 4.1) and subsequently updating the transportation and utility lifeline databases. Many of the suggestions will also be applicable to other types of facilities, such as essential facilities and government buildings. However, some of the GIS and database concepts may not be applicable to buildings because the HAZUS®MH general building stock data is contained in multiple related tables. For guidance on updating the general building stock, users should refer to Chapter 5.

This chapter is intended as a general technical guide for GIS users. Sections 4.2 and 4.3 outline GIS and database methods for creating data layers for HAZUS®MH and automation of the various data compilation processes.

4.1 Identifying Alternative Sources of Lifeline Data for HAZUS®MH

Various federal, state, and local agencies collect and maintain geospatial data. These datasets may be useful for loss estimation within HAZUS®MH, or as supplementary data for emergency response purposes. The following Section will help HAZUS®MH users to locate alternative transportation and utility lifeline data, for which potential sources are summarized in Table 4.1 and Table 4.2.

4.1.1 Using On-line Sources to Compile Attributes

The Internet can be an excellent source for GIS data. As a first step towards developing a comprehensive list of agencies distributing data for the designated area of interest, it is advisable to use a web search engine, such as Google™ (www.google.com). For building and lifeline information, county planning or GIS departments, public works agencies, and tax assessor's offices are good places to start. Websites for agencies, organizations, committees, or individuals well known in the industry may also yield potential data sources. Users may wish to restrict online searches to government sites by including the phrase "site:gov". Once a promising site is located, it is possible to restrict a search to a specific domain. For example, the OES site can be searched by including "site:www.oes.ca.gov" in the search. Often, it is useful to include common GIS file extensions in a search.

Online GIS portals like Geospatial One-Stop (GOS), also known as geodata.gov, can be a valuable resource for locating alternate data for lifelines. GOS is a government initiative sponsored by the Federal Office of Management and Budget (OMB) serving as a public gateway for access to geospatial information and data. The GOS portal is a catalog of geospatial information containing thousands of metadata records and links to live maps,

features, catalog services, downloadable data sets, images, clearinghouses, map files, and more. The portal is very useful to gain quick access to featured relevant data in the data categories, search a wide variety of geographic information, view metadata, interact with map services and publish data and search for partners for data collections and acquisitions.

Table 4.1. Alternate Data Sources for Transportation Lifeline Data

LIFELINE COMPONENT OR FACILITY	DATA SOURCES	CONTACT
Highway segments	NHPN	FHWA website
	HPMS	
Highway bridges	NBI	FHWA Office of Bridge Technology
	PONTIS, Caltrans bridges	State Bridge Engineer and PONTIS website
Railway tracks	NTAD	USDOT, BTS
Railway bridges Railway tunnels	NBI	FHWA Office of Bridge Technology
	Caltrans Bridges	State Bridge Engineer
Railway facilities	NTAD	USDOT, BTS
	Caltrans GIS	Caltrans GIS analyst
Light rail track segments	Local light rail agencies	Light Rail engineer/personnel
	Caltrans GIS	Caltrans GIS analyst
Light rail bridges	Local light rail agencies	Light Rail engineer/personnel
	NBI	FHWA Office of Bridge Technology
Light rail tunnels Light rail facilities	Local light rail agencies	Light Rail engineer/personnel
Bus facilities	Caltrans GIS	Caltrans GIS analyst
	Amtrak, Greyhound	Bus Agency websites
Ferry facilities	USACE	USACE Engineering personnel
	Caltrans GIS	Caltrans GIS analyst
Ports and harbors facilities	USACE	USACE websites/ GIS personnel
	Port of Los Angeles/ Long Beach/ Oakland	Port Authority Officials
Airports facilities Airports runways	FAA	FAA websites/ GIS personnel
	Local Airports	Local Airport officials

Note: For a guide to acronyms used in this table, please refer to Section 4.1.3.

Table 4.2. Alternate Data Sources for Utility Lifeline Data

LIFELINE COMPONENT OR FACILITY	DATA SOURCES	CONTACT
Potable water pipelines	Local or regional water utilities	City or County Public Works Engineers, Local water utility or wastewater personnel
Potable water distribution lines	HAZUS®MH distribution pipeline data	FEMA website
	2000 U.S. Census TIGER files	US Census Bureau website
Potable water facilities	HAZUS®MH potable water facilities data	FEMA website
	2000 U.S. Census TIGER files	US Census Bureau website
	Discussions and interviews with local water agency personnel, and field observations.	City or County Public Works Engineers, Local water utility personnel
Wastewater pipelines	Local or regional water utilities	City or County Public Works Engineers, Local wastewater personnel
Wastewater collection lines	HAZUS®MH wastewater collection pipeline data	FEMA website
Wastewater facilities	Local or regional wastewater utilities	City or County Public Works Engineers, Local water utility or wastewater personnel
Oil pipelines	USDOT NPMS	OPS GIS manager
	EIA GIS-NG	EIA website
Oil facilities	EIA GIS-NG	EIA website
	State Fire Marshals Office	State Fire Marshal
Natural gas pipelines Natural gas facilities Natural gas distribution lines	EIA GIS-NG	EIA website
	USDOT NPMS	OPS GIS manager
	Local or regional utility	Local or regional utility personnel
Electric power facilities	EIA GIS-NG	EIA website
	FERC	FERC website
	Local or regional utility	Local or regional utility personnel
Communication facilities	FCC	FCC personnel
	Local telecommunication	Local telecommunication personnel
Communication distribution cables	2000 U.S. Census TIGER files	US Census Bureau website

Note: For a guide to acronyms used in this table, please refer to Section 4.1.3.

4.1.2 Benefits of Personal Contact as a Follow-up to Data Sources Identified On-line

Once potential data sources have been identified, the associated metadata should be reviewed to assess the applicability for a specific project. If possible, it is advisable to contact the agency to discuss the data (for example, there may be mistakes in metadata, and descriptions are easy to misinterpret), and confirm its applicability. This is also a good opportunity for the user to discuss the project, so that the agency knows how their data is being used. Furthermore, agency analysts may suggest additional data sources. When contacting analysts or managers by telephone, it is useful to have a form letter ready to fax, mail, or e-mail with an official project description and references.

4.1.3 Public and Private Sources of GIS Data for California

Although many databases are technically within the public domain, public agencies may be reluctant to release their data due to security concerns. However, most public agencies are forthcoming, especially when the user makes clear how the data will be used, and when that use is for a public good. In addition to those specific agencies identified in Tables 4.1 and 4.2, agencies that may have various statewide data include:

- California Geological Survey (http://www.consrv.ca.gov/cgs/)
- California Land Science Information Partnership (http://ceres.ca.gov/calsip/)
- California Spatial Information Library (http://www.gis.ca.gov/)
- California Public Utilities Commission (http://www.cpuc.ca.gov/)
- Caltrans Office of GIS Data Library (http://www.dot.ca.gov/hq/tsip/TSIPGSC/library/libdatalist.htm)

In the private sector, the following companies redistribute public data for free, or at low cost:

- Environmental Systems Research Institute (http://www.esri.com/data/)
- GIS Data Depot (http://data.geocomm.com/)

In addition, federal data warehousing programs often have detailed HAZUS®MH-compatible data, which can be found through technical list-serves, bulletin boards, online GIS data libraries, geography departments, and government search directories. The federal agencies or programs listed below and in Tables 4-1 and 4-2 have provided data or information used in HAZUS®MH:

BTS Bureau of Transportation Statistics (www.bts.gov/)

EIA Energy Information Administration (http://www.eia.doe.gov/)

EIA NG GIS	EIA Natural Gas Geographic Information System (http://www.eia.doe.gov/)
EPA	Environmental Protection Agency (http://www.epa.gov/)
FAA	Federal Aviation Administration (http://www.faa.gov/)
FCC	Federal Communications Commission (http://www.fcc.gov/)
FEMA	Federal Emergency Management Agency (http://www.fema.gov/hazus/)
FERC	Federal Energy Regulatory Commission (www.ferc.gov/)
FERC Form 1	Federal Energy Regulatory Commission Form 1 (http://rimsweb2.ferc.fed.us/form1viewer/)
FHWA	Federal Highway Administration (www.fhwa.dot.gov/)
HPMS	Highway Performance Monitoring System (http://www.fhwa.dot.gov/policy/ohpi/hpms/)
NBI	National Bridge Inventory (http://www.fhwa.dot.gov/bridge/nbi.htm)
NERC	North American Electric Reliability Council (www.nerc.com)
NHPN	National Highway Planning Network (http://www.fhwa.dot.gov/planning/nhpn/index.html)
NPMS	National Pipeline Mapping System (http://www.npms.rspa.dot.gov/)
NTAD	National Transportation Atlas Database (http://www.bts.gov/programs/geographic_information_services/download_sites/ntad02/maindownload.html)
OPS	Office of Pipeline Safety (www.ops.dot.gov/)
USACE	U.S. Army Corps of Engineers (www.usace.army.mil/)
USDOT	United States Department of Transportation (www.dot.gov/)

Provided below is a list of all the public agency departments that may maintain lifeline inventory data in digital format:

- City and County Planning Department
- City and County Building Department
- Landuse and Environmental Planning
- Transportation Planning/ Engineering
- Geographic Information System Department
- Mapping Systems Department

- Public Works Department
- City Utility Agencies like Water, Wastewater
- City and County Office of Emergency Services (OES)
- Information Systems Department
- Information Technology (IT)
- Fire Department
- Sherrif's Department
- Information Services (IS)
- Research Centers associated with Cities or Counties

Frequently, a data quest may identify a data set that is comprehensive geographically, but with little attribute data necessary for determining the appropriate HAZUS®MH facility class and other necessary parameters, such as replacement cost. It is recommended that users contact local agency personnel or engineers to discuss the appropriate HAZUS®MH classification and to collect other necessary data, such as capacity or replacement cost. Even when default GIS data is not being updated, agency personnel can be contacted for replacement cost data for key components, or to verify or spot check HAZUS®MH defaults. For transportation or utility lifelines, local utility agencies, port authority personnel, and transportation authority officials are good sources for replacement cost data on facilities and components that contribute significantly to losses. Benefit-cost studies generated for mitigation or capital improvement programs are also a useful source for cost data. A good example is the Federal Aviation Authority (FAA) Benefit Cost Analysis division, whose data and reports have been used to value public non-commercial airports and private landing strips.

4.1.4 Data Derived from Remote Sensing Imagery

High-resolution remote sensing data can provide a geo-referenced photographic backdrop, allowing an analyst to make adjustments to a lifeline facility's location or key attributes. It may also prove useful where accurate height, building footprint, or location is required for specific facilities. High-resolution satellite images that offer the newest innovations in remote sensing technology consists of the IKONOS (from Space Imaging) and OrbView (from Orb Image), both of which offer imagery as fine as 1-m resolution. QuickBird (from DigitalGlobe) offers the highest resolution presently available from commercial satellites (61 cm). In addition, digital aerial images offer a number of advantages in the remote-sensing acquisition of lifeline inventory data. Because of the low altitudes possible for aerial imaging, these systems can offer imagery with higher spatial resolutions than satellite-imaging systems. Some of the commercial aerial image data providers include Eagle Aerial, Aerials Express and Pictometry. USGS Digital Orthophoto Quarter Quads (DOQQ) are available for much of the US for the cost of distribution, but the data may not be current for a given area. ECW imagery from ER Mapper (http://earthetc.com) also provides many remote sensing data sets for free, including high resolution imagery for California. An example using high resolution imagery to update attribute information of a lifeline table is provided below.

The default Ports and Harbors table in HAZUS®MH can be updated using federal data from USACE and BTS. However, important data denoting whether a crane is stationary or rail-mounted is not available from these sources. This information is essential for determining the HAZUS®MH classification (and resulting vulnerability) for the crane. In Figure 4.1, which shows part of a USGS DOQQ, it is easy to see the rails, and conclude that the cranes would be classified as rail-mounted for analysis within HAZUS®MH.

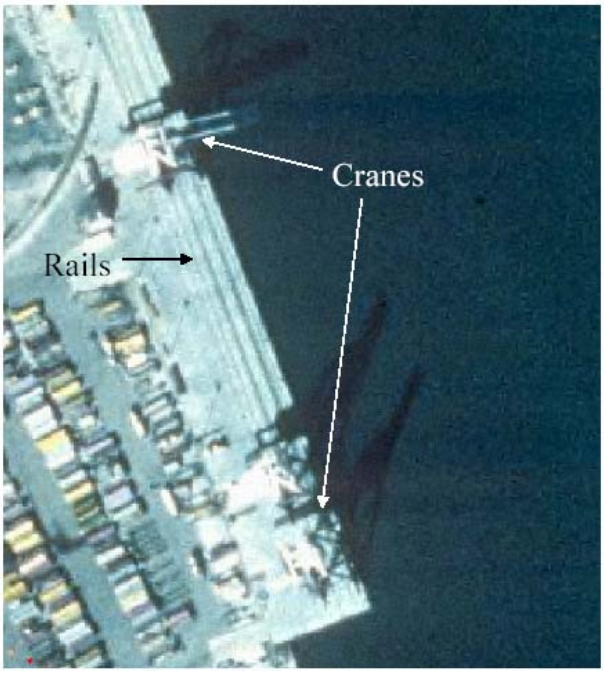


Figure 4.1. Rail Mounted Cranes in a Port Facility

4.1.5 Refining Default Lifeline Facility Replacement Costs Based on Facility Size or Capacity

Default replacement costs for transportation and lifeline utility facilities should be reviewed, and updated when necessary. Improved replacement cost estimates can be found by contacting transportation and utility agencies or data sources such as those identified in Tables 4.1 and 4.2 and discussed in the previous sections, or may be refined from HAZUS®MH default values based on available facility data, such as size or capacity data.

When detailed data is collected for a specific HAZUS®MH study region, the default costs associated with broader classes may not be representative. For example, HAZUS®MH categorizes water treatment plants as small (capacity of <50 million gallons per day or MGD), medium (50-200 MGD), or large (greater than 200 MGD). The capacity ranges associated with the three classes are broad, and if the user is able to collect very detailed data, the costs associated with the three facility classes may not reflect the true variability in facility size and replacement cost. Water treatment facilities can be as small as 5 to 10 MGD. Using the default replacement cost HAZUS®MH would overestimate dollar losses

from damage to such facilities. By plotting the HAZUS®MH default replacement cost against the average capacity (in MGD) for the classes, it is possible to derive an equation reflecting the HAZUS®MH default assumptions ($400,000 replacement cost for each MGD in capacity). By applying this type of replacement cost equation to the more detailed database collected by the user, the resulting loss estimates would be improved.

4.2 Updating Default Lifeline data in HAZUS®MH

HAZUS®MH is distributed with a set of default data. Depending on the quality and vintage of the default data in HAZUS®MH, and the availability of enhanced data, a user may want to use, partially replace or completely replace a given HAZUS®MH table. Before updating any HAZUS®MH table, it is recommended that the user save a copy of the original data by backing up the study region.

Generally, databases on transportation and utility lifeline systems available from different sources vary in format. The user needs to convert point or line features in various formats (for example ArcView Shape, MapInfo Tab file, image files or database tables) into standard ArcGIS geodatabases (MDB) with HAZUS®MH data structure. Details of this ArcView Shape to Geodatabase conversion process (for hazard maps) is presented in Appendix K of the HAZUS®MH User Manual (DHS/FEMA, 2005). Geodatabases are relational databases that contain geographic information. Geodatabases contain feature classes (which store geographic features represented as points, lines, or polygons) and tables (which store attributes of the feature classes). Information on the HAZUS®MH data structure can be accessed through the *Database Dictionary* which is available interactively in the HAZUS®MH program. Figure 4.2 shows an example screen shot of the *Database Dictionary*. A detailed *Database Dictionary* containing the names and structures of all of the databases in HAZUS®MH is also provided in the HAZUS®MH MR-1 Technical Manual (DHS/FEMA, 2005).

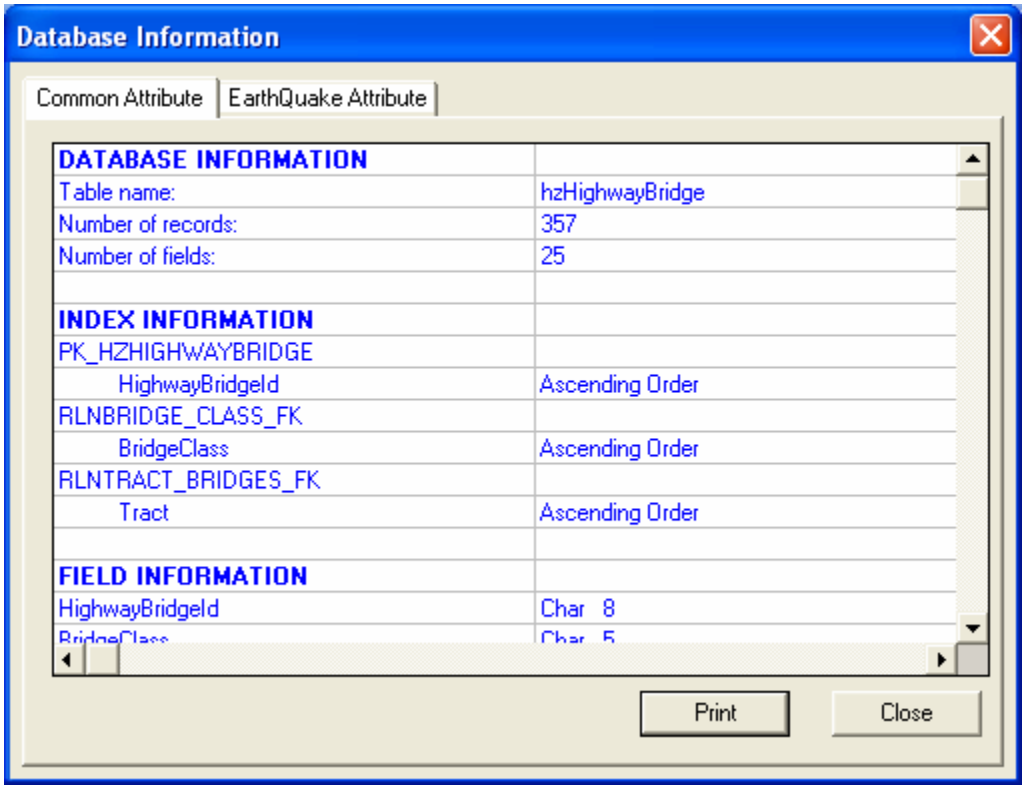


Figure 4.2. Example Screenshot of HAZUS®MH Interactive Database Dictionary

4.2.1 Importing Point Features Using HAZUS®MH Data Import Utility

HAZUS®MH lifeline inventory data include transportation lifeline point features and utility lifeline point features. The major transportation lifeline categories (for example highway, railway, ports and harbors, etc) are broken down into facility components. The transportation components that are point features in HAZUS®MH include:

- Highway Bridges
- Highway Tunnels
- Railway Bridges
- Railway Tunnels
- Railway Facilities
- Light Rail Bridges
- Light Rail Tunnels
- Light Rail Facilities
- Bus Facilities
- Ports and Harbors Facilities
- Ferry Facilities
- Airports Facilities
- Airports Runways[6]

6 In HAZUS, airport runways are represented geographically as point data, with attribute data tabulating runway length and other parameters.

Similarly, the major utilities lifeline categories (for example potable water, wastewater, electric power, etc) are also broken down into facility components. The utility components that are point features in HAZUS®MH include:

- Potable Water Facilities
- Paste Water Facilities
- Natural Gas Facilities
- Oil Systems Facilities
- Electric Power Facilities
- Communication Facilities

To perform the update of a particular HAZUS®MH table with new data, the user needs to convert the new data into ArcGIS geodatabase format (MDB) with the HAZUS®MH data structure. As mentioned earlier in this section, the HAZUS®MH data structure for all lifeline tables is available interactively through the Data Dictionary (See Figure 4.2) or HAZUS®MH MR-1 Technical documentation. Once the new data is formatted into a geodatabase conforming to the HAZUS®MH table structure, it can be imported using the *Data Import Utility* available through the HAZUS®MH interface.

The *Data Import Utility* enables the updating of lifeline inventory a user intends to change or improve. The following sections outline the steps involved in importing point features using the *Data Import Utility*.

The user selects the inventory he/she intends to update from the HAZUS®MH Inventory menu (See Figure 4.3) and starts the editing process (by using the mouse, left-click on a record, then right-click and choose “Start Editing”, see Figure 4.4). Once in the “Edit” mode, “Import” will appear in bold on right-clicking the mouse (See Figure 4.5). The user then specifies the location of the database (Directory and Filename) with the new data he/she intends to import (See Figure 4.6). The user then uses the mapping window shown in Figure 4.7 to map the each field in the new database (source) to the corresponding field used in the HAZUS®MH database (target). The user should note that it is not required that the order of the field names in the source and the target databases be the same. Once the mapping of fields between the user supplied database and the HAZUS®MH database is completed, the imported database is displayed within the HAZUS®MH study region.

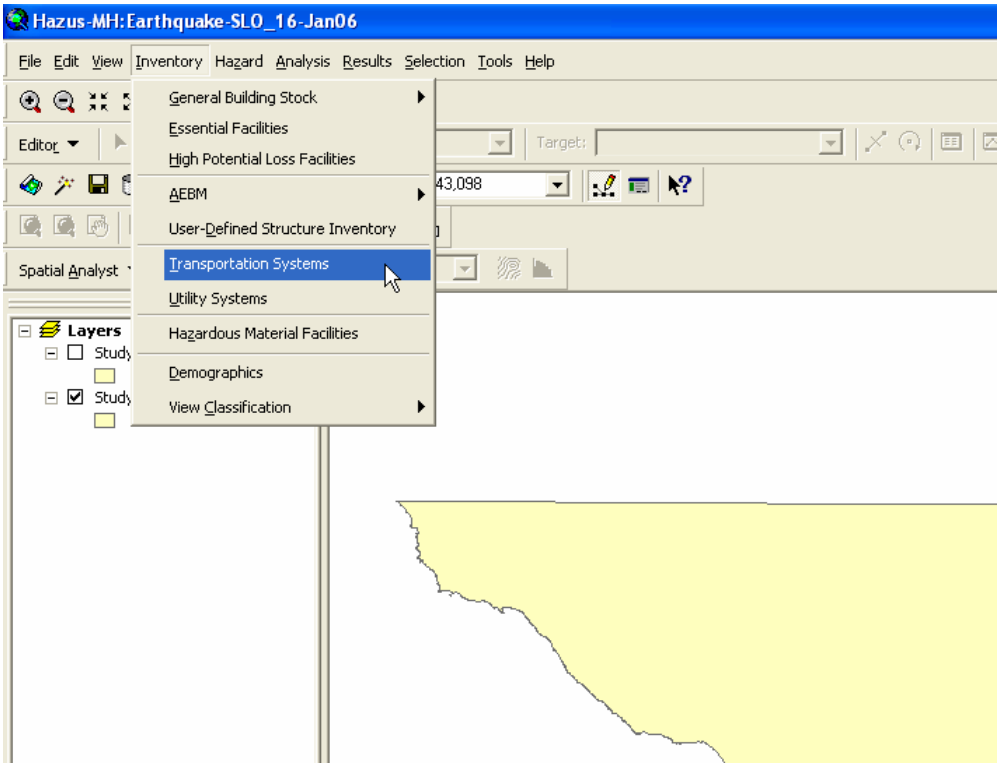


Figure 4.3. Selecting the Lifeline Inventory to Update

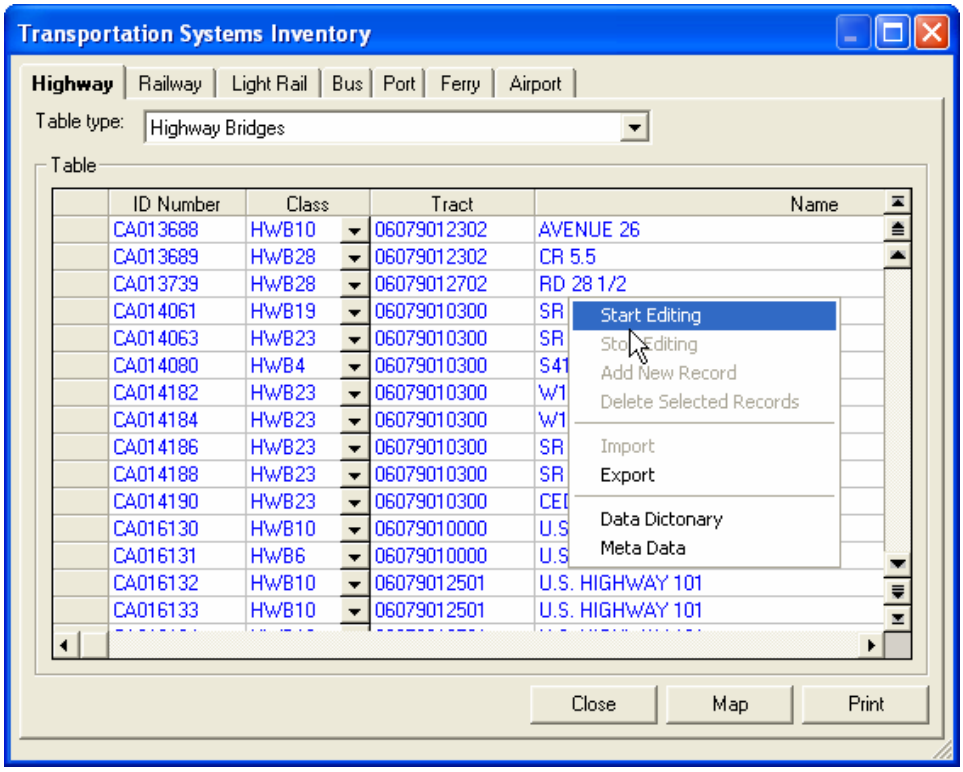


Figure 4.4. Starting the Editing Process to Import Data

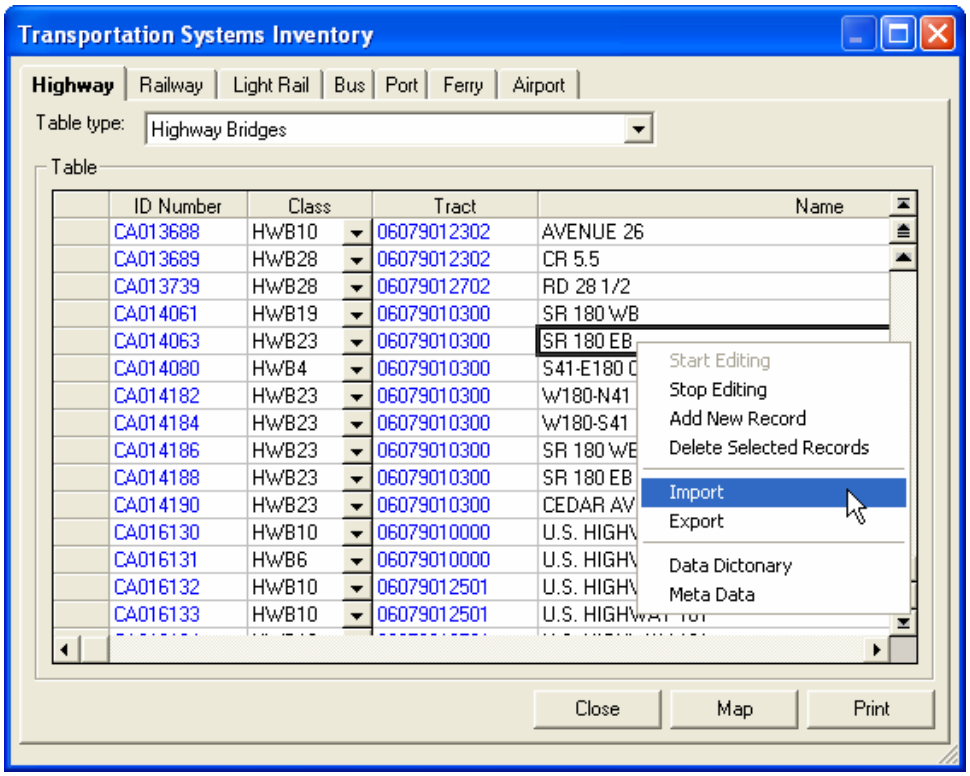


Figure 4.5. Importing Lifeline Point Features with Attributes

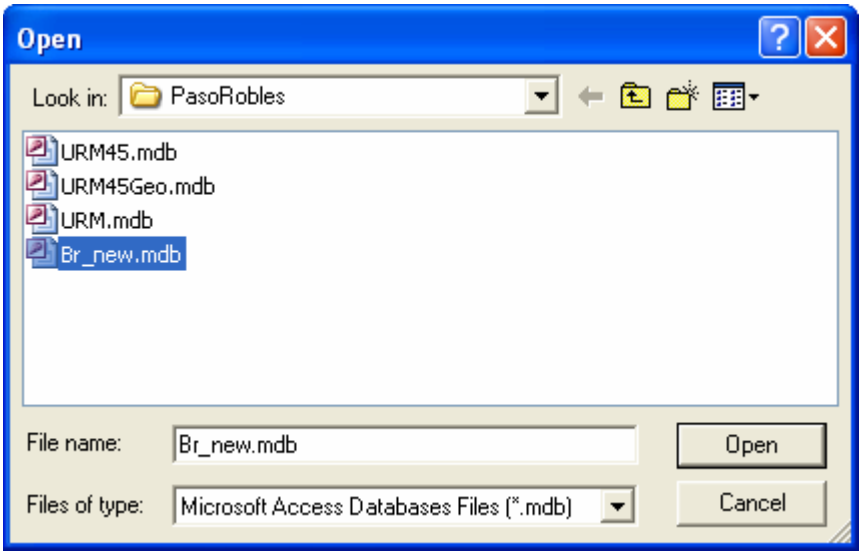


Figure 4.6. Identify the Database with New Data to be Imported

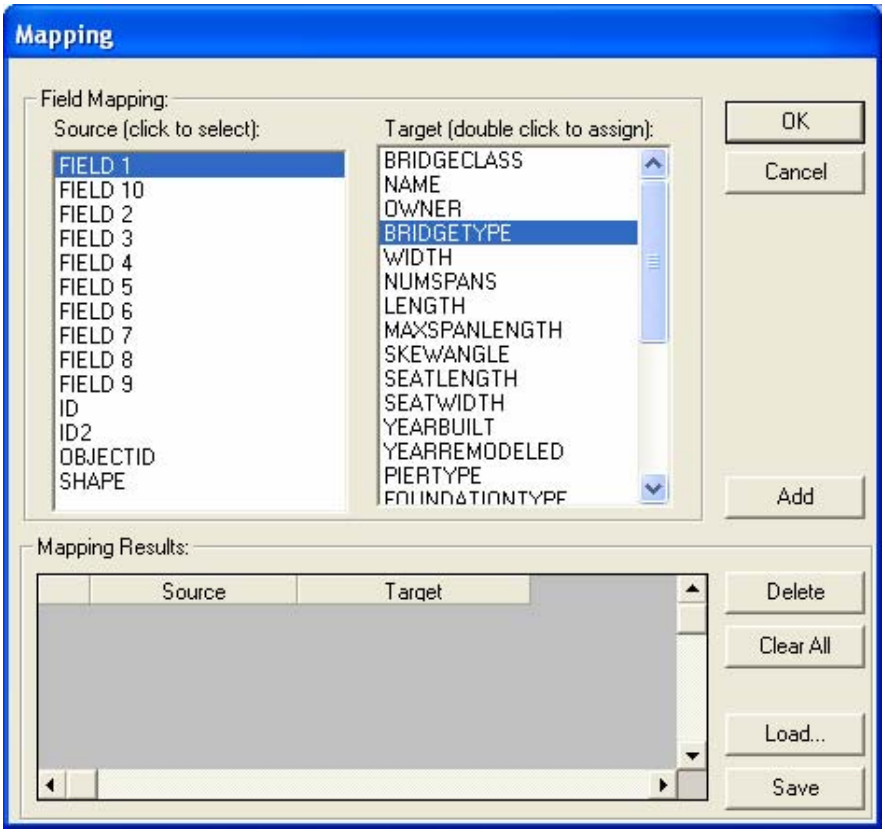


Figure 4.7. Mapping the Fields of New Data File to the HAZUS®MH Data Structure

4.2.2 Importing Linear Features Using HAZUS®MH Data Import Utility

HAZUS®MH lifeline inventory data include transportation lifeline linear features and utility lifeline linear features. The major transportation lifeline categories (for example highway, railway, light rail, etc) are broken down into various components. The transportation components that are linear features in HAZUS®MH include:

- Highway Segments
- Railway Track Segments
- Light Rail Track Segments

Similarly, the major utilities lifeline categories (for example potable water, wastewater, electric power, etc) are also broken down into various components. The utility components that are linear features in HAZUS®MH include:

- Potable Water Pipeline Segments
- Wastewater Pipeline Segments
- Oil Pipelines Segments
- Natural Gas Pipelines Segments

As described in the previous Section, to perform the update of a particular HAZUS®MH table with new data, the user needs to convert the new data into ArcGIS geodatabase format (MDB) with the HAZUS®MH data structure. Also, the HAZUS®MH data structure for all lifeline tables (point and linear features) is available interactively through the *Data Dictionary* (See Figure 4.2) or HAZUS®MH MR-1 Technical documentation.

As discussed in the case of point features, a database with linear features can also be imported into a HAZUS®MH study region using the Data Import Utility to improve or update the default data. The steps involved in importing the linear features are similar to those discussed in 4.2.1.

4.2.3 Using the HAZUS®MH Study Region Map to Add Point or Linear Features

In addition to importing point or linear databases (methods described in Sections 4.2.1 and 4.2.2), a user can add, edit or delete individual features interactively through the HAZUS®MH interface for a particular study region. The following steps describe the method to update individual lifeline records if a user has better data available and chooses to improve the default inventory.

Adding Features Using the Study Region Map

Through the HAZUS®MH interface, a user is only able to access feature locations and a few additional fields for a particular table. For example, if the user opens the highway bridge attribute table (See Figure 4.8), only the ObjectID, Shape, HighwayBridgeID, Tract, Latitude and Longitude fields are listed. The remaining set of feature attributes such as BridgeType, NumSpans, Width and MaxSpanLength are stored in an underlying SQL Server database. This design for feature and attribute storage is for efficiency and involves the following steps to add features to a database:

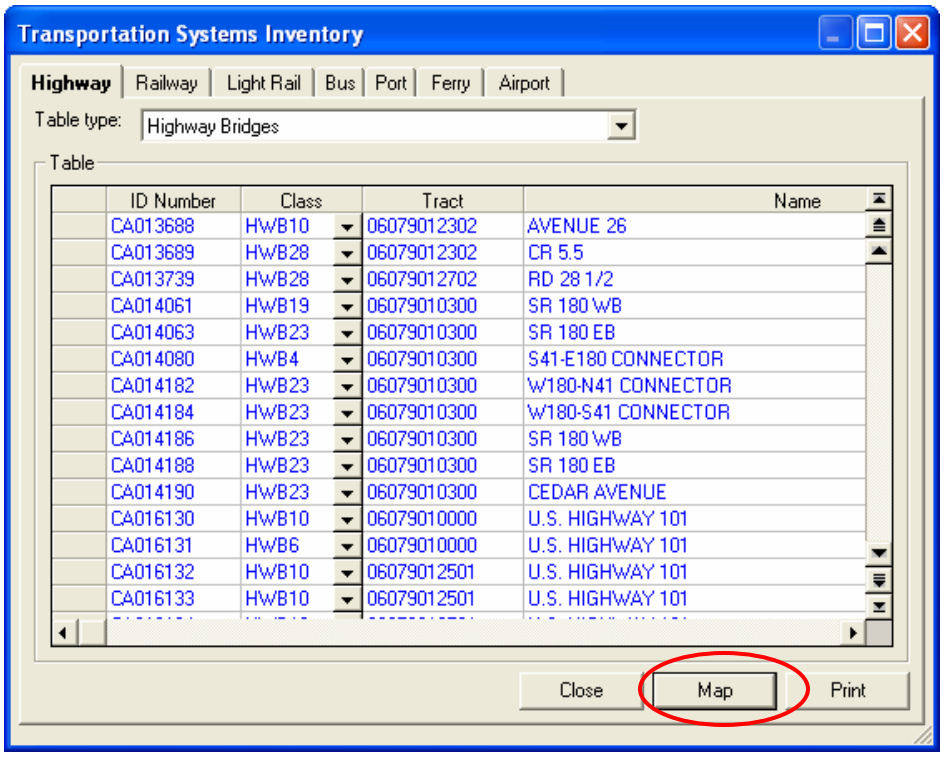
Attributes of hzHighwayBridge

OBJECTID*	SHAPE*	HighwayBridgeId*	Tract*	Longitude	Latitude
1	Point	CA013688	06079012302	-120.335000	35.126670
2	Point	CA013689	06079012302	-120.44333	35.10167
3	Point	CA014061	06079010300	-120.338890	35.593060
4	Point	CA014063	06079010300	-120.338890	35.593060
5	Point	CA014080	06079010300	-120.338890	35.593060
6	Point	CA014182	06079010300	-120.338890	35.593060
7	Point	CA014184	06079010300	-120.338890	35.593060
8	Point	CA014186	06079010300	-120.338890	35.593060
9	Point	CA014188	06079010300	-120.338890	35.593060
10	Point	CA014190	06079010300	-120.338890	35.593060
11	Point	CA016130	06079010000	-120.696670	35.718330
12	Point	CA016131	06079010000	-120.696670	35.718330
13	Point	CA016132	06079012501	-120.70333	35.530000
14	Point	CA016133	06079012501	-120.70333	35.530000
15	Point	CA016134	06079012501	-120.70333	35.528330
16	Point	CA016135	06079012501	-120.70333	35.528330
17	Point	CA016136	06079012702	-120.60333	35.393330
18	Point	CA016137	06079012702	-120.640000	35.368330
19	Point	CA016138	06079011101	-120.67	35.275000
20	Point	CA016140	06079011101	-120.67	35.275000
21	Point	CA016142	06079011700	-120.63667	35.136670
22	Point	CA016143	06079012200	-120.62333	35.103330
23	Point	CA016144	06079011600	-120.700000	35.185000
24	Point	CA016145	06079011600	-120.700000	35.185000
25	Point	CA016146	06079011700	-120.635	35.140000
26	Point	CA016147	06079011700	-120.635	35.140000
27	Point	CA016148	06079011700	-120.635	35.140000

Record: 13 Show: All Selected Records (0 out of 357 Selected.) Options

Figure 4.8. Highway Bridge Attribute Table Accessed through the HAZUS®MH Interface

1. Map the table the user selects to edit (See Figures 4.9a and 4.9b). For example, if the user wants to edit the highway bridge table, select the transportation systems inventory from the HAZUS®MH "Inventory" menu. The first tab is the highway bridge inventory. Click on the "map" button to add the bridge layer to the map.



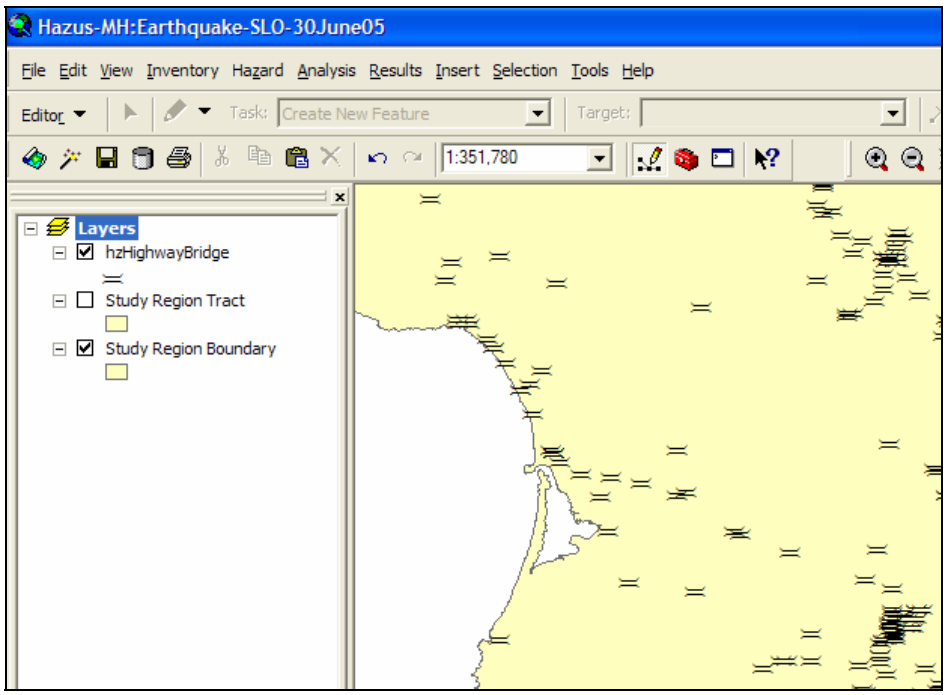


Figure 4.9. Opening the Transportation System Inventory and Mapping Highway Bridge Table

2. Start Editing using the ArcMap Editor toolbar (See Figure 4.10)

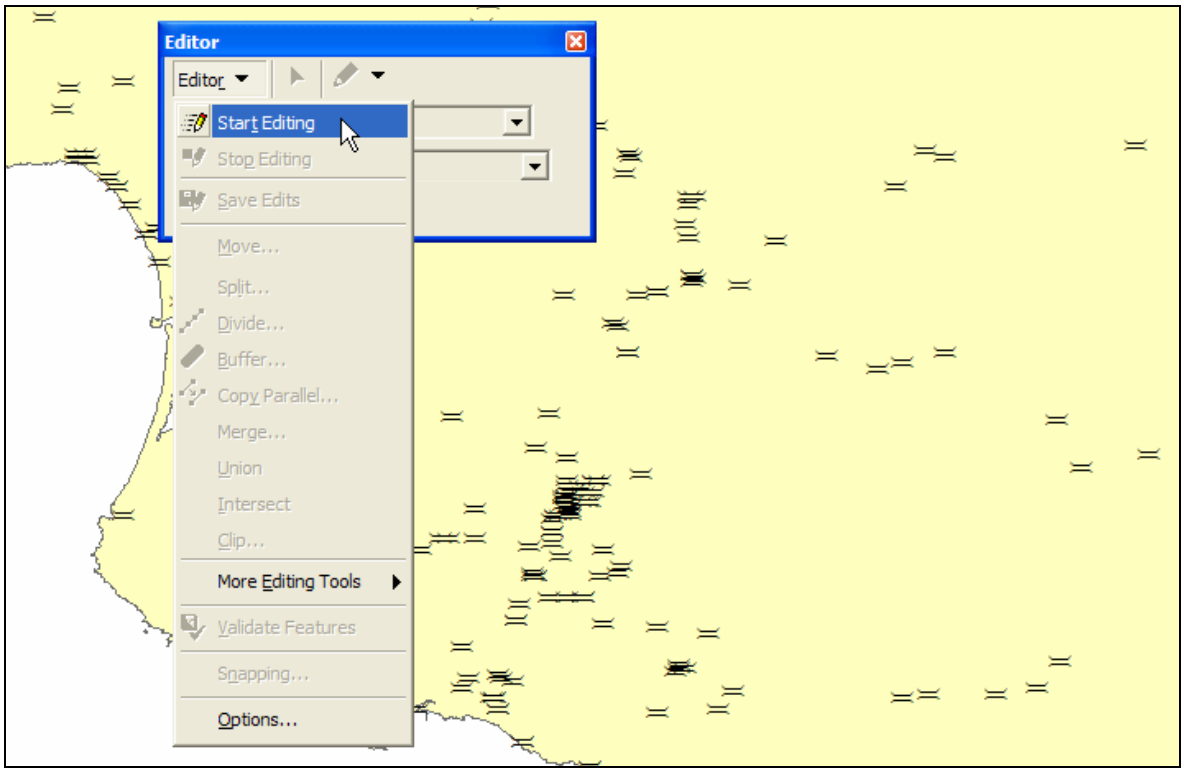


Figure 4.10. Editing the Highway Bridge Table through the ArcMap Editor

3. Select the appropriate geodatabase to edit. For example if the user is editing highway bridges select the trn.mdb database (Figure 4.11).[7]

7 Study region specific geodatabases are stored within the HAZUS-MH study region folder. For example a user editing "Study Region A", may access the transportation geodatabase at the following location: "\Program Files\HAZUS-MH\Study region A\TRN.mdb"

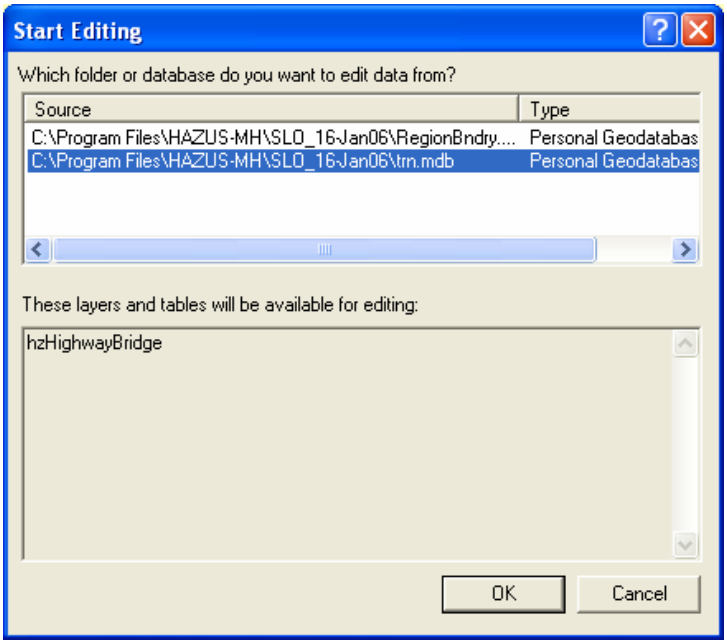


Figure 4.11. Selecting the Database to Edit

4. Add point (or linear) features using the Sketch tool in the Editor toolbar (Figure 4.11). Once adding features is complete, select Stop Editing features from the Editor toolbar (See Figure 4.13).

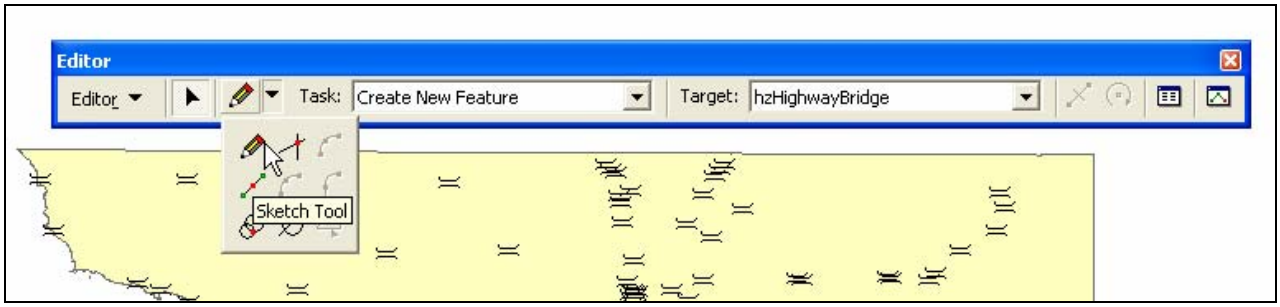


Figure 4.12. Adding New Features Using the Editor Tool

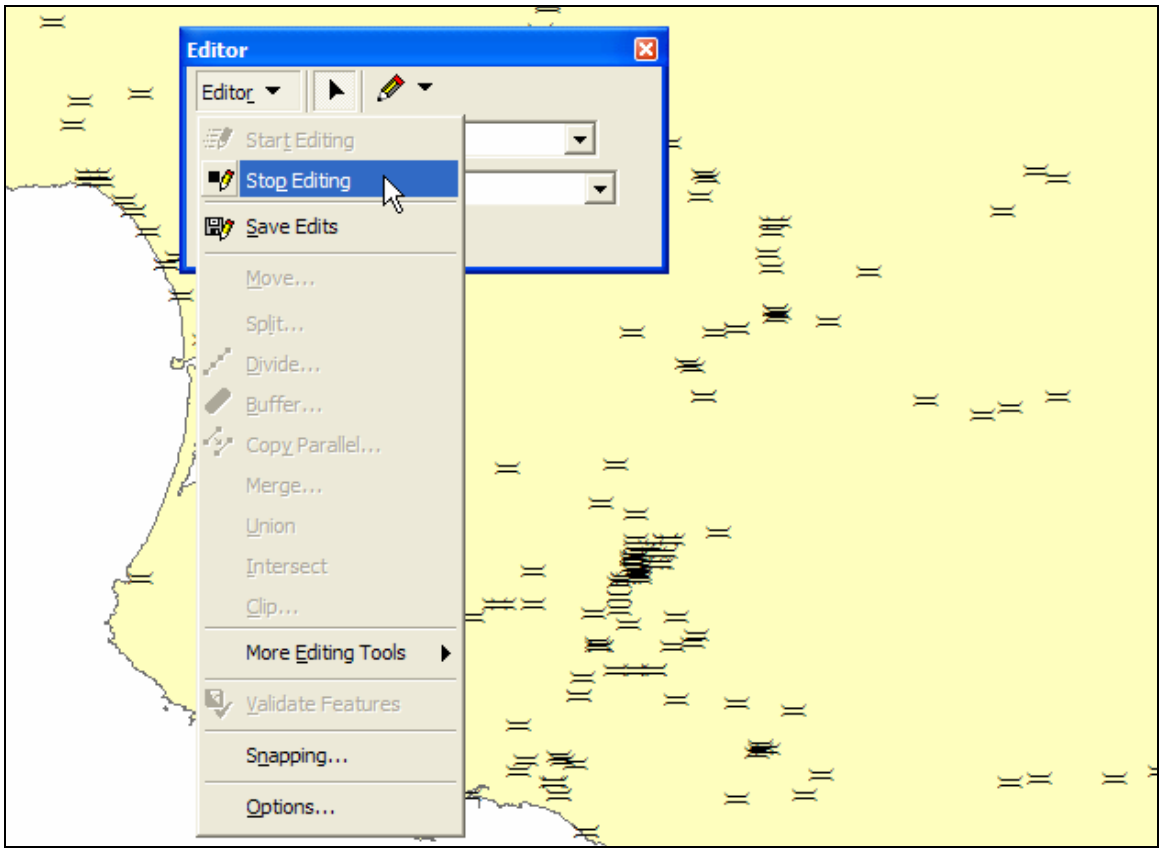


Figure 4.13. Stopping the Editing Process

5. This step links attribute information to the newly added features. From the HAZUS®MH Inventory menu, open the inventory being updated. For example, open the highway bridge table if the user added new highway bridge points in the study region map. Add attributes to each new feature record by placing the cursor in the appropriate field. Note that the feature ID field cannot be edited. When adding records, all inventory data features must fall within the study region boundary. If feature locations are outside the study region, HAZUS®MH does not add them to the inventory table.

   The location attributes for a point feature are the fields that need to be populated at the minimum. If the location is not added graphically the alternative way to define a facility location in HAZUS®MH is to type in the longitude and latitude of the facility interactively by making an inventory table editable.

4.2.4 Editing HAZUS®MH Tables with Point or Linear Features

Attributes associated with default or improved point and linear features can be edited directly through the HAZUS®MH interface. From the HAZUS®MH Inventory menu, select the database to edit. To delete existing features, select the record to be deleted from a database by clicking on the record marker on the left side of the record ID. When the

record is selected, use the right mouse button to display the database management options, and choose Delete Selected Records. Right-clicking the mouse on the spreadsheet, placing the cursor in the desired cell, and replacing the text to be modified can edit data within a record.

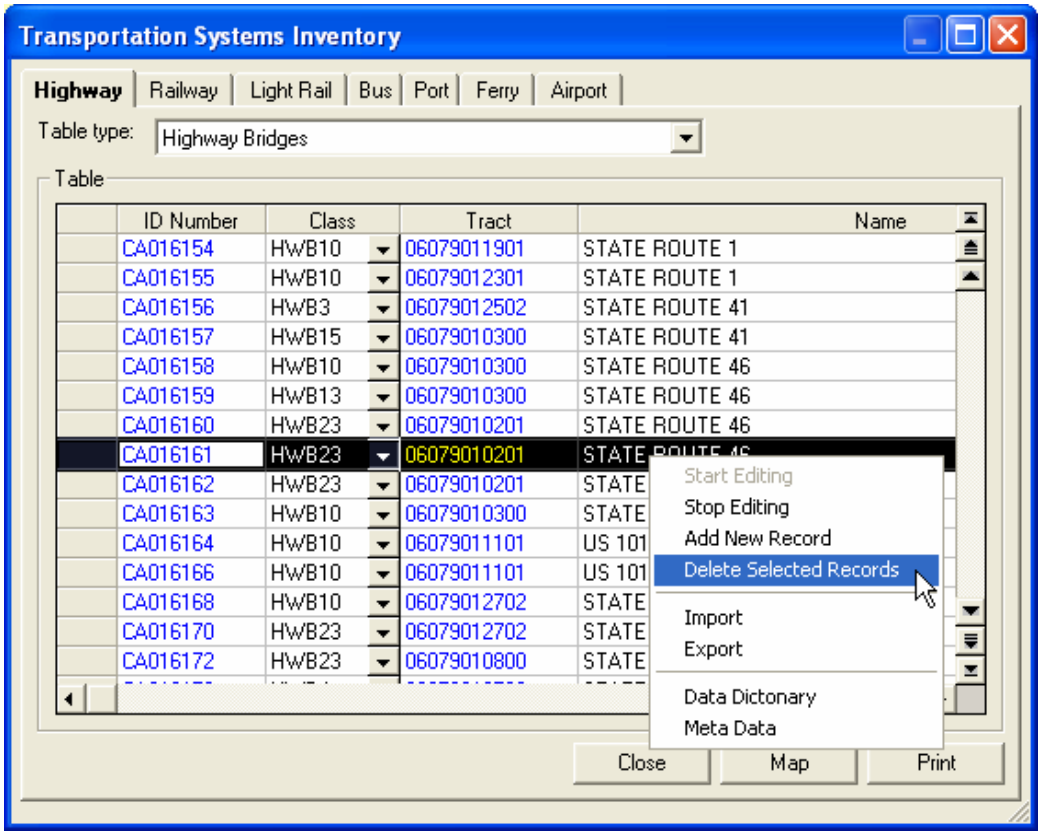


Figure 4.14. Editing HAZUS®MH Tables through the Software Interface

4.3 Common Database Principles and GIS concepts for Updating HAZUS®MH Input Tables

For a study region, HAZUS®MH stores all lifeline database information in SQL Server using Microsoft's free SQL Server MSDE 2000. Accessing and updating these data tables for a study region is possible through Microsoft Access by establishing an Open Database Connectivity (ODBC) entry to the HAZUS®MH MR-1 study region. A description of how to create this connection is provided for building inventories in Appendix C: Building Inventory Replacement Tool (BIRT). This process is also applicable for Lifelines. Once a new Data Source to SQL Server is established through Microsoft Access, a user can then use this data source to link to the various inventory tables and update attributes. This process is particularly effective for update queries for addressing problems such as inappropriate replacement cost. To update tables with new features, it is recommend that the user makes changes through the HAZUS®MH user interface whenever possible.

Updating the underlying lifeline tables without using the HAZUS®MH user interface is only recommended for advanced users, after backing up a study region. HAZUS®MH support will not troubleshoot either the process of updating HAZUS®MH or any problems associated with study regions that have been updated outside of the user interface. Users that apply these methods are advised to follow the general data checking principles outlined in Chapter 6: Data Checking, and to revert to previously saved study regions when it is suspected that there may be any problems with the update process. At a minimum, it is recommended that users run a default HAZUS®MH alongside the updated study regions and compare the results carefully.

When creating databases for input into HAZUS®MH, the user should adhere to common database principles. This will help streamline the process of updating HAZUS®MH tables, eliminate potential errors due to referential integrity, and avoid most table formatting issues. It is advised that users employ existing HAZUS®MH tables as templates whenever a replacement table is created. Please refer to SQL Server documentation for details on how to implement basic database functions.

It is recommended that users always maintain a unique identifier that allows association with the original database. This will allow for future updates or data verification. It is further recommended that the user save all queries or SQL statements associated with each data layer, to facilitate subsequent updates. As always, the user is cautioned to back up all the data frequently.

Complete table replacement in SQL Server is recommended for advanced users only. Please refer to SQL Server documentation for details on how to implement basic database functions. Users should follow the database principles outlined above, make a copy of the table, open the copy, delete all features, and use "append" queries to add data. Users can then rename the original table to a backup, and rename the copy to reflect the original table name. To replace a selected subset of records in the table, use "select" queries by specified criteria if the records have unique identifiers and common fields. Use smart geographic selection (for further details see Section 4.3.1) for records with no common fields or unique identifiers. Use "append" queries to add selected data into an existing table.

Append queries can be used for attaching data to new or existing HAZUS®MH tables, based on a criteria. The user should add unique ID fields to both existing and new records if they are not already present. Then append the records. Save all SQL query statements to a text file associated with each data layer. It is likely that the user will have to repeat these steps several times.

4.3.1 Using Attribute Data in Various Formats to Update Lifeline Tables

Electric power facilities (tables hzElectricPowerFlty, eqElectricPowerFlty) are a very important contributor to total economic loss associated with lifelines. Attribute information for electric power facilities is often available in text or tabular format.

However, for security reasons, it is often difficult to obtain in GIS format. Some data gathering is possible through field observation and via interviews with utility personnel.

Generally, there are disparities between relevant databases on a particular lifeline system available from various sources. For example, USGS Digital Line Graphs generally provide good spatial information, which may be used to locate substations, but lack accompanying attribute information. FERC Form 1 data provides good quality attribute data that may be used to supplement power and substation information, however, it is non-spatial.

Together, these two databases may be used to replace default data in the HAZUS®MH tables. The default HAZUS®MH electric power facility database contains some data, generally limited to substations and not including power plants. To completely replace electric power facility data, a new table can be created by saving the default HAZUS®MH table under a new filename, and deleting all features from it. A series of queries are then run to identify plants that should be added from the electric power data, and this data should be appended to the new table. The attributes for these facilities should be updated with the new attribute data. These modifications are significantly more complicated in SQL Server than in the dBase files associated with previous versions of HAZUS®MH, and are recommended for advanced users only. Please refer to SQL Server documentation for details on how to implement basic database functions.

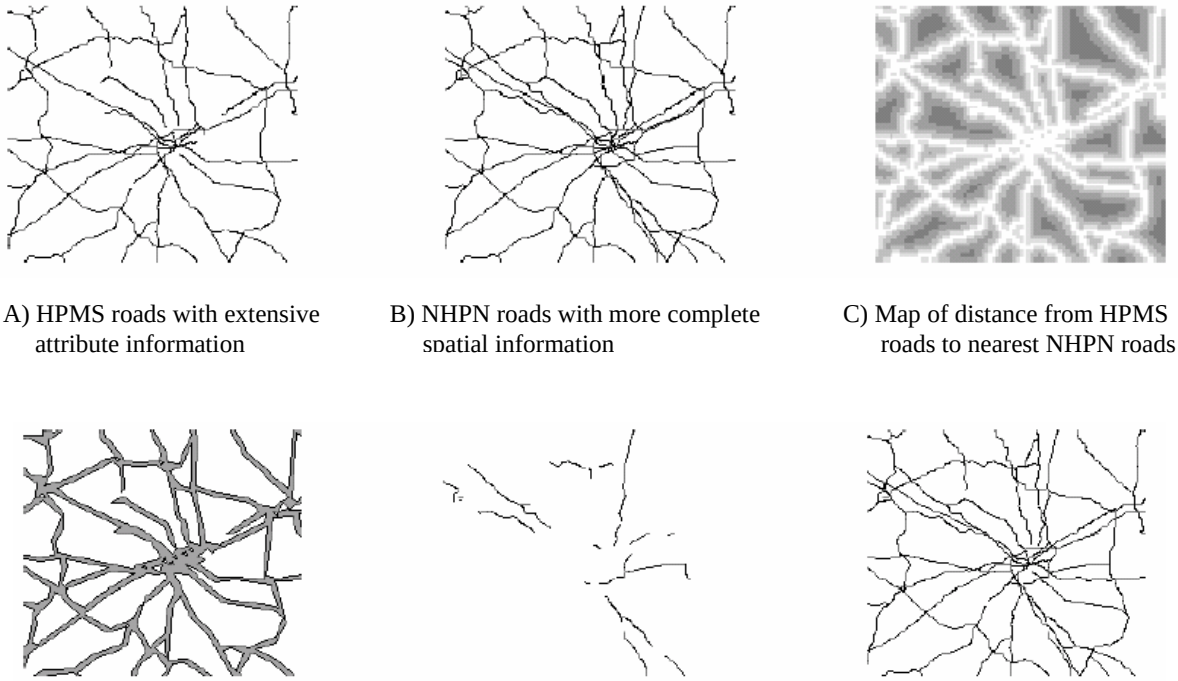
4.3.2 Merging Data to Create New HAZUS®MH Dataset and Resolving Multiple Database Issues

Merging datasets is the process of creating a new layer from two or more input data layers. This procedure is very useful for updating the HAZUS®MH default databases that have geographic components. This is particularly helpful when default records need to be replaced with more accurate or more detailed data, or when the defaults no longer represent current conditions.

In some cases, merging a limited number of facilities can be done by manually selecting items from a list. However, if there are many features and a unique ID is not available, the process of merging data can require geographic selection. For example, one data set may be more accurate for rural areas, and another may be more accurate for urban areas. In this case, an analyst would use city boundaries to spatially select features in the urban dataset. For the rural data, the city boundaries would also be used to select features in the cities, but then the selected rows would be reversed, leaving the rural facilities. Finally, an analyst would append them to a single HAZUS data layer. Another common method for merging spatial data is to count facilities by zip code in each database. The analyst can then select features amongst each of the datasets, where the count by zip code is highest.

When an analyst must merge linear or polygonal data, the process becomes more complex, and may require either buffering or distance calculations. An illustrative example involving highway data is provided in Figure 4.15 below. One source of

highway data, the Highway Performance Monitoring System (HPMS), contains comprehensive lane information (see Figure 4.15, illustration A) while another data set from the National Highway Planning Network (NHPN) has more spatial features (see Figure 4.15, illustration B). In order to merge these datasets, a fine grid could be created that measures the distance in miles from features in the database with fewer road features (HPMS) to the nearest road link in the other (NHPN) database (see Figure 4.15, illustration C). After visually inspecting the road networks overlaid with the grid, it might be determined that a half mile would be a sufficient distance for separating the highway networks, and so grid cells with values smaller than 0.5 would be converted to a single polygon. Figure 4.15, illustration D, depicts the step that converts the "buffered" HPMS road links to a polygon. Road links in the more detailed spatial database (NHPN) that have their centers outside of this buffer zone (e.g., not represented in the HPMS database) would then be selected and a new coverage would be created from these features. The result of this selection process is shown in Figure 4.15, illustration E, which identifies the features of the majority of NHPN segments not included in the HPMS file. The selected NHPN data in the new coverage would then be merged with the HPMS dataset, to create a highway table with more complete attribute data (results shown in Figure 4.15, illustration F).



A) HPMS roads with extensive attribute information

B) NHPN roads with more complete spatial information

C) Map of distance from HPMS roads to nearest NHPN roads

D) Areas very close to HPMS

E) roads outside of HPMS zones, appended to HAZUS file

F) Selected HPMS and NHPN roads

Figure 4.15. Example of Merging Road Network Databases

The merging of multiple databases can be difficult, but when successful, leads to a more robust data set. Multiple datasets with accurate attributes are often available for one type of input. For example, it is not uncommon to receive a database with very precise geographic location data but little structural information, and receive a different database with complete structural information but no geographic attributes. Where there is no common ID, joining the two databases may pose a challenge. In this situation, resolving the databases requires creative solutions, based on implied location, similar contact information, or explicit geographic location.

4.3.3 Automation of Processes to Create or Update HAZUS®MH Input Tables

Updating data tables in HAZUS®MH, or replacing defaults with better quality data, may require numerous repetitious data processing tasks. Almost any repetitive process can be automated. Although process automation and batch processing using Procedural-SQL, MapBasic, Visual Basic for Applications, and even DOS batch files may take additional time to develop, in the long run it could save time.

As an example, process automation is useful when updating the HAZUS®MH highway bridge table with recent National Bridge Inventory (NBI) data. NBI data is updated every year and the database format does not usually change. Integrating new NBI data involves adding new items to the database and replacing older information on existing bridges. This can be done automatically by querying the unique ID to identify bridges already present in the default database, and using append queries to add the new structures. For the existing bridges, the user could build and maintain a macro that updates the HAZUS®MH table each time a new NBI database is published.

5. Updating Building Inventory Data in HAZUS®MH MR-1 and the Use of Inference Algorithms

As described in Section 3.3 and Table 3.4 (repeated as Table 5.1), a variety of building inventory databases within HAZUS®MH are high or medium priority candidates for update. While tools have been developed to facilitate the updates (MaSC and BIRT), data required to implement these updates ranges in complexity from straightforward published cost factors and replacement cost data available from R.S. Means, to complex distributions of structural type by occupancy derived from Assessor's data. It should be noted that a variety of commercial vendors such as Experian, Metroscan, and Dataquick offer publicly-available property-related data for resale. While the private vendors do provide value-added data services, such as validation, data-cleaning, and enhancement with data from other sources, the data required by HAZUS will either be included in the original Assessor's data or is expected to be unavailable from the Assessor or from other available sources. For government-related applications, it is recommended that the user contact the local Assessor first, although commercial data providers may be seen as a potential resource.

In the more complex cases, available data (including Assessor's data) may be insufficient for the development of the required distributions, and the user will need a strategy for filling in the data gaps. For example, many Assessor's databases maintain data on structure type in five general classes, which must somehow be translated into the 324[8] HAZUS®MH MR-1 model building types (see Table 2.5 and Section 2.4.2). This translation is typically accomplished using available Assessor's data on structure type, occupancy, age and height, along with local structural engineering expert opinion. A translation such as this would be referred to as an inference algorithm, whereby available data is used to methodically infer something about missing data.

This chapter describes in detail the requirements for updating each of the Medium and High priority building inventory data updates identified in Table 5.1 (and Table 3.4). While little construction or structural engineering knowledge is required for the simpler updates, some of the more complex updates may require inference algorithms or knowledge of local construction practices and their changes over time. Because historic local construction practices vary throughout the state, it would not be possible to provide the user with inference algorithms that could be applied statewide. Instead, the intent of these guidelines is to describe the update process, including the inference algorithms, and whenever possible, provide examples from previous updates and inference algorithms in a variety of locations throughout the state. These examples take the form of "lessons learned" from previous experience, each focusing on a particular aspect of the various update procedures and presented at the end of each update's section. These sections provide a summary of the lesson learned in a box at the top of the section (e.g., for

[8] The 324 different model building types result from the combination of 36 basic model building types and height variations, with 3 seismic design levels and 3 building quality classes.

policy-level user), as well as detailed descriptions of the implementation process (for hands-on GIS and database users).

For each recommended update discussed, results from the Phase One study and the Phase Two pilot tests (data evaluations for ten pilot communities, with detailed data processing implementation for two of the communities; San Luis Obispo County and Los Angeles County) have been considered in providing guidance to the user. That is, if the previous and current efforts revealed a common data gap, the guidelines offer suggestions on how best to fill the gap, as well as provide guidelines for when better data is available.

Table 5.1. Candidate General Building Stock Inventory Data Updates and Data Requirements

No.	Update Strategy	Required Data	Update Prioritization
Level 1 Updates			
1A* Sect. 5.2.1	Using the BIRT, update the HAZUS replacement cost model tables (replacement cost per square foot, by occupancy)	Updated Means (or other local) building replacement cost models (all cost models contained in HAZUS®MH MR-1 are based on Means 2002, while HAZUS®MH MR-2 uses Means 2005). *The BIRT default update reflects the 2005 models contained in HAZUS®MH MR-2. The user may also change the model contained in BIRT to reflect local input or expert opinion.*	**HIGH**
1B* Sect. 5.2.1	Using the BIRT, update the Means-based Regional Cost Modifier to reflect increase in costs over time as well as location factors.	Historical Cost Index data provided in Means "Square Foot Costs" Publication, or from other sources. *The BIRT default update reflects the 2005 models contained in HAZUS®MH MR-2. The user may also change the model contained in BIRT to reflect local input or expert opinion.*	**HIGH**
1C* Sect. 5.2.1	Using the BIRT, update the HAZUS contents value model (contents value estimated as a percent of structure value, by occupancy)	Estimated contents value expressed as a percent of structure value, by occupancy. (Note: the contents value model in HAZUS®MH MR-2 is identical to the model in HAZUS®MH MR-1). *The user may change the model contained in BIRT to reflect local input or expert opinion.*	**HIGH** whenever building replacement cost is updated.
1D* Sect. 5.2.1	Using the BIRT, update the General Building Stock Square Footage Factors used to estimate building counts from square footage data.	Estimate of typical size of building, by occupancy. May be obtained from expert opinion or from processed Assessor's data (i.e., building occupancy information, square footage data, association of Assessor's occupancy classes with HAZUS®MH occupancy classes). Typical building sizes utilized in HAZUS®MH MR-1 are based on Means 2002, while HAZUS®MH MR-2 uses Means 2005. *The BIRT default update reflects the 2005 models contained in HAZUS®MH MR-2. The user may also change the model contained in BIRT to reflect local input or expert opinion.*	**HIGH** when BIRT is used to update from MR-1 baseline (2002) to MR-2 baseline (2005), or when square footage data is updated without updating building count.

* Note: it is strongly recommended that when using BIRT to update from MR-1 baseline (2002) to MR-2 baseline (2005), that all the four Level 1 updates (Updates 1A, 1B, 1C and 1D) be completed at the same time. That is, these four updates should be done as a "suite" of updates.

Table 5.1. Candidate General Building Stock Inventory Data Updates and Data Requirements (continued)

No.	Update Strategy	Required Data	Update Prioritization
Level 2 Updates			
2 Sect. 5.2.2	Using the BIRT, update the census tract-based "Square Footage – Occupancy" table from Assessor's data.	Assessor's data on building occupancy, square footage, and census tract location for each building/parcel	**HIGH** (if Assessor's database has been geocoded and/or census tract location is known) **MEDIUM** (if Assessor's database has not been geocoded.)
3 Sect. 5.2.3	Through the HAZUS®MH GUI, update the general mapping scheme (overall percent distribution of building square footage across basic structural types – wood, concrete, steel, masonry, manufactured housing – by occupancy) from Assessor's data.	Assessor's data on building occupancy, square footage, and construction class.	**MEDIUM**
4 Sect. 5.2.4	Using the BIRT, update the census tract-based "Building Count" table from Assessor's data	Assessor's data on building occupancy, and census tract location for each building/parcel.	**MEDIUM** (if Assessor's database has been geocoded and/or census tract location is known) **LOW** (if Assessor's database has not been geocoded.)
5 Sect. 5.2.5	Using the HAZUS®MH Advanced Engineering Building Module (AEBM), analyze unreinforced masonry structures on a building-by-building basis	Inventory of URM structures, compilation of which is required by the California Seismic Safety Commission. Requires geocoding and may require additional data collection (occupancy, square footage, number of occupants)	**HIGH** (if data is geocoded, especially if general mapping scheme is updated from Assessor's data) **MEDIUM** (if not geocoded.)
6 Sect. 5.2.6	Using the MaSC, update the specific occupancy detailed mapping schemes to better reflect the distribution of building heights across the entire study region, or create a separate mapping scheme for application in downtown urban centers.	Requires data on distribution of building height by occupancy and model building type (structural type), or more likely, data on distribution of building height by occupancy (no knowledge of distribution by model building type)	**MEDIUM**
7 Sect. 5.2.7	Using the MaSC (or through the HAZUS GUI), update the specific occupancy detailed mapping schemes to better reflect the distribution of particularly vulnerable structures (e.g., URM, NDCF, tilt-up).	Data on usage of vulnerable building types within the community (e.g., SSC inventory of URM buildings), other occupancy and construction data from Assessor's database, inference algorithms	**MEDIUM**

Table 5.1. Candidate General Building Stock Inventory Data Updates and Data Requirements (continued)

No.	Update Strategy	Required Data	Update Prioritization
Level 2 Updates (Continued)			
8 Sect. **5.2.8**	Using the BIRT, update square footage distribution by census tract, based on census updates (available approx. every 4 years)	Growth ratios by census tract derived from HAZUS®MH census data and updated census data (must be within same decade, otherwise census tracts may change)	**CURRENTLY LOW** (default inventory is based on 2000 census data; priority will increase over time, as growth continues and 2000 census data becomes outdated)

5.1 What is an Inference Algorithm?

Dictionary.com defines "inference" and "algorithm" as follows:
Inference:

1. *The act or process of deriving logical conclusions from premises known or assumed to be true.*
2. *The act of reasoning from factual knowledge or evidence.*

Algorithm:

A step-by-step problem-solving procedure, especially an established, recursive computational procedure for solving a problem in a finite number of steps.

In the context of using local data to improve on the default data provided with HAZUS®MH MR-1, inference algorithms refer to general procedures a user could follow to make use of available data (e.g., Assessor's data on square footage, age, use, height or basic structural type) to replace or refine data or distributions required by HAZUS®MH. In some cases, the inferences required of the user are straightforward, such as associating each detailed occupancy or use code in the Assessor's data with the 33 occupancy types in HAZUS®MH. Other inferences are more complex, such as when structural engineering input may be required to develop a distribution of "steel" structures according to the 117 different HAZUS®MH model building types for steel (4 structural classes with 3 possible height classes, plus 1 strictly low-rise class, for a total of 13 different models), seismic design level (3 levels) and seismic performance levels (3 levels).

5.2 Guidelines for Implementing High and Medium Priority Building Inventory Updates in HAZUS®MH

5.2.1 Update #1: Suggested Level 1 Updates Using BIRT

BIRT "Level 1" updates require no additional data, and allow the user to update:

A. The HAZUS replacement cost model (national average cost per square foot for buildings of various occupancies) used to generate building exposure ($) values by census tract and occupancy (see Tables 2-9 and 2-10). BIRT allows the user to update HAZUS®MH MR-1 values (2002 cost models) to the latest HAZUS cost model (HAZUS®MH MR-2, 2005 cost models). Alternatively, the user can edit the replacement cost model to better reflect local conditions. (See Appendix C – "Using BIRT" for more information.)
B. The HAZUS Means-based location factor used to "localize" national costs to reflect local conditions, used to generate building exposure ($) values by census tract and occupancy (see Table 2-11). BIRT provides the latest HAZUS location factors for residential and non-residential construction (HAZUS®MH MR-2, 2005) to allow the user to update HAZUS®MH MR-1 values (2002 models) to more current values. The location factors may also be used project future costs. (See Appendix C for more information on BIRT, and "R.S. Means Square Foot Costs" for a detailed discussion on the use of location factors.)
C. The HAZUS default model for contents value, estimated as a percent of building replacement value (see Table 2-12).
D. The HAZUS default model for typical building size by occupancy, used to derive building counts from square footage data (see Table 2-8).

It is strongly recommended that when using BIRT to update from MR-1 baseline (2002) to MR-2 baseline (2005), that all the four Level 1 updates (Updates 1A, 1B, 1C and 1D) be completed at the same time. That is, these four updates should be done as a "suite" of updates.

5.2.2 Update #2: Updating the Census Tract-Based "Square Footage – Occupancy" Table from Assessor's Data (Level 2 Updates Using BIRT)

The default general building stock data in HAZUS®MH is aggregate proxy data developed from 2000 census data (for residential structures) and similar vintage Dun & Bradstreet data (for commercial structures). This data is a good candidate for update because local data is expected to be more precise, will reflect buildings constructed since the 2000 census was conducted, and because this database is the fundamental starting point for damage and loss estimates.

Data required to perform this update include:

- Building occupancy information – generally available in Assessor's databases.
- Square footage data – generally available in Assessor's databases.
- Census tract location for each building/parcel – often available from County Planning or GIS Departments.

The basic steps required to implement this update are as follows:

1. Ensure that for each building, data from the Assessor on occupancy and square footage are readily available in database format ("Assessor's data").
2. Associate each detailed assessor's occupancy class with one of the 33 HAZUS®MH occupancy classes. In other words, build a table ("Occupancy key") listing each Assessor's occupancy class and assign each one to an appropriate HAZUS®MH occupancy class. For most uses, the association of Assessor's use or occupancy code to HAZUS®MH occupancy class (given in Table 2-4) is straightforward, based on the HAZUS occupancy class description. In some cases, appropriate assignment may require review of the detailed SIC (Standard Industrial Classification) code assignments used in the original HAZUS occupancy class definition. Table 5-2 provides the list of HAZUS occupancy classes and associated SIC codes from the HAZUS®MH Earthquake Technical Manual (Table 3.20), as well as the SIC Code definitions taken from the full listing of SIC codes and definitions, available on-line at: http://www.osha.gov/pls/imis/sic_manual.html. Some Assessor's use or occupancy codes are not specifically identified in the SIC Code list in Table 5-2. For these codes, the on-line search feature at the noted website can be used to identify an appropriate SIC category and HAZUS occupancy assignment.
3. For each building or parcel, obtain the latitude and longitude data from the County Planning or GIS department. Have a GIS Analyst overlay the lat/long locations of all buildings onto maps of 2000 census tract boundaries, and build a table ("Parcel – Census Tract") listing each parcel number or building identifier and its associated census tract identifier.
4. Within a database program (such as Microsoft Access), link the "Assessor's data", "Occupancy key", and "Parcel-Census Tract" tables, and aggregate total building square footage (in units of 1000 square feet) by HAZUS®MH occupancy class for each census tract.
5. Following the square footage table template provided with BIRT ("ASSR_Template.MDB"), reformat as required.

Table 5.2. HAZUS Occupancy Classes and Associated SIC Codes and Definitions (see: http://www.osha.gov/pls/imis/sic_manual.html for more information)

Label	Occupancy Class	SIC Code(s)	SIC Code Definition
RES1	Single Family Dwelling		
RES2	Mobile Home		
RES3	Multi Family Dwelling		
RES4	Temporary Lodging	70	Hotels, Rooming Houses, Camps, And Other Lodging Places
RES5	Institutional Dormitory		
RES6	Nursing Home	8051 8052 8059	Skilled Nursing Care Facilities Intermediate Care Facilities Nursing and Personal Care Facilities, Not Elsewhere Classified
COM1	Retail Trade	52 53 54 55 56 57 59	Building Materials, Hardware, Garden Supply, And Mobile Home Dealers General Merchandise Stores Food Stores Automotive Dealers and Gasoline Service Stations Apparel and Accessory Stores Home Furniture, Furnishings, And Equipment Stores Miscellaneous Retail
COM2	Wholesale Trade	42 50 51	Motor Freight Transportation and Warehousing Wholesale Trade –durable Goods Wholesale Trade –non-durable Goods
COM3	Personal/ Repair Services	72 75 76 83 88	Personal Services Automotive Repair, Services, And Parking Miscellaneous Repair Services Social Services Private Households

Label	Occupancy Class	SIC Code(s)	SIC Code Definition
COM4	Prof./ Technical Services	40 41 44 45 46 47 49 61 62 63 64 65 67 73 78 (except 7832) 81 87 89	Railroad Transportation Local And Suburban Transit And Interurban Highway Passenger Transportation Water Transportation Transportation By Air Pipelines, Except Natural Gas Transportation Services Electric, Gas, And Sanitary Services Non-depository Credit Institutions Security And Commodity Brokers, Dealers, Exchanges, And Services Insurance Carriers Insurance Agents, Brokers, And Service Real Estate Holding And Other Investment Offices Business Services Motion Pictures Legal Services Engineering, Accounting, Research, Management, And Related Services Miscellaneous Services
COM5	Banks	60	Depository Institutions
COM6	Hospital	8062 8063 8069	General Medical and Surgical Hospitals Psychiatric Hospitals Specialty Hospitals, Except Psychiatric
COM7	Medical Office/ Clinic	80 (except 8051, 8052, 8059, 8062, 8063, 8069)	Health Services
COM8	Entertainment & Rec.	48 58 79 (except 7911) 84	Communications Eating And Drinking Places Amusement And Recreation Services Museums, Art Galleries, And Botanical And Zoological Gardens
COM9	Theaters	7832 7911	Motion Picture Theaters, Except Drive-In Dance Studios, Schools, and Halls
COM10	Parking		

Label	Occupancy Class	SIC Code(s)	SIC Code Definition
IND1	Heavy	22 24 26 32 34 35 (except 3571, 3572) 37	Textile Mill Products Lumber And Wood Products, Except Furniture Paper And Allied Products Stone, Clay, Glass, And Concrete Products Fabricated Metal Products, Except Machinery And Transportation Equipment Industrial And Commercial Machinery And Computer Equipment Transportation Equipment
IND2	Light	23 25 27 30 31 36 (except 3671, 3672, 3674) 38 39	Apparel And Other Finished Products Made From Fabrics And Similar Materials Furniture And Fixtures Printing, Publishing, And Allied Industries Rubber And Miscellaneous Plastic Products Leather And Leather Products Electronic And Other Electrical Equipment And Components, Except Computer Equipment Measuring, Analyzing, And Controlling Instruments; Photographic, Medical And Optical Goods; Watches And Clocks Miscellaneous Manufacturing Industries
IND3	Food/Drugs/ Chemicals	20 21 28 29	Food And Kindred Products Tobacco Products Chemicals And Allied Products Petroleum Refining And Related Industries
IND4	Metals/Minerals Processing	10 12 13 14 33	Metal Mining Coal Mining Oil And Gas Extraction Mining And Quarrying Of Nonmetallic Minerals, Except Fuels Primary Metal Industries
IND5	High Technology	3571 3572 3671 3672 3674	Electronic Computers Computer Storage Devices Electron Tubes Printed Circuit Boards Semiconductors and Related Devices
IND6	Construction	15 16 17	Building Construction General Contractors And Operative Builders Heavy Construction Other Than Building Construction Contractors Construction Special Trade Contractors

Label	Occupancy Class	SIC Code(s)	SIC Code Definition
AGR1	Agriculture	01 02 07 08 09	Agricultural Production Crops Agricultural production livestock and animal specialties Agricultural Services Forestry Fishing, hunting, and trapping
REL1	Church/ N.P. Offices	86	Membership Organizations
GOV1	General Services	43 91 92 (except 9221, 9224) 93 94 95 96 97	United States Postal Service Executive, Legislative, And General Government, Except Finance Justice, Public Order, And Safety Public Finance, Taxation, And Monetary Policy Administration Of Human Resource Programs Administration Of Environmental Quality And Housing Programs Administration Of Economic Programs National Security And International Affairs
GOV2	Emergency Response	9221 9224	Police Protection Fire Protection
EDU1	Schools	82 (except 8221, 8222)	Educational Services
EDU2	Colleges/ Universities	8221 8222	Colleges, Universities, and Professional Schools Junior Colleges and Technical Institutes

5.2.2.1 Lessons Learned: Associating Assessor's Occupancy or Use Codes with HAZUS®MH Occupancy Classes

Lesson Learned: In general, Assessors databases will have more use or occupancy classes than the 33 utilized within HAZUS®MH. In order to use Assessor's data within HAZUS®MH (e.g., to replace square foot occupancy tables or update mapping schemes), the user must associate each of the Assessor's use classes with a HAZUS®MH occupancy class. Most of the associations are straightforward, with a few exceptions. It is recommended that mixed-use occupancies (e.g., apartment house and commercial store) be classified into the predominant occupancy (the occupancy representing the majority of the building square footage). In the rare case when Assessor's occupancy classes are generic (e.g., "industrial"), the user should consider disaggregating the generically classified data into HAZUS®MH' specific occupancies in proportion to their representation in the HAZUS®MH default square-footage occupancy table.

In conjunction with a regional earthquake risk research project, ABS Consulting used Assessor's data from San Francisco County to update default HAZUS® inventory databases (in HAZUS®99). An early step in this analysis was the association of Assessor's use codes with HAZUS® occupancy classes. Although this effort was performed using HAZUS®99, the lessons learned are also applicable to HAZUS®MH. Table 5.3 lists Assessor's use codes for San Francisco City and County, and the associated HAZUS®99 occupancy class utilized in the study. As shown, mixed-use occupancy classes (e.g., "Apartment House And Commercial Store", "Hotel Plus Commercial Units") do occur. In these cases, the occupancy was classified according to the predominant use. That is, if most of the building square footage was expected to be dedicated to apartments, the building was classified as an apartment building

An important step in the San Francisco study was the replacement of the HAZUS®99 default square footage occupancy table with a table based on local data, including data from the Assessor. In theory, this is based on a simple aggregation of Assessor's square footage data by census tract (or other geographic unit) and HAZUS® occupancy. An issue arose, however, because of the generic "Industrial" use code in the Assessor's database. Because HAZUS® uses six different industrial occupancy classes (IND1, Heavy Industrial; IND2, Light Industrial; IND3, Food/Drugs/ Chemicals; IND4, Metals/Mineral Processing; IND5, High Technology; and IND6, Construction Offices), some assumptions were required to distribute the actual building square footage classified by the Assessor as "Industrial" across the 6 HAZUS® industrial classes.

A review of the HAZUS®99 default square footage occupancy data for San Francisco provided the distribution of industrial square footage shown in Table 5.4. While the actual square footage data from the Assessor is expected to be more accurate than the HAZUS® default, the relative distribution among the various industrial sub-classes in the default data (which is based on employment and other data) is assumed to provide a reasonable representation of the relative contribution of each sub-class. Accordingly, to develop the detailed square footage occupancy table from Assessor's data, the relative percentages for each industrial sub-class (e.g., IND1, IND2, etc.) from the HAZUS®99 default were applied to the total actual "industrial" square footage from the Assessor's

data to estimate the distribution among the various HAZUS® industrial occupancy classes.

Table 5.3. Association of Assessor Use Codes with HAZUS®99 Occupancy Classes for San Francisco City/County

San Francisco County Assessor's Use Code	HAZUS®99 Occupancy Class	HAZUS®99 Occupancy Class Description
Dwelling (One Unit)	RES1	Single Family Dwelling
Apartment House	RES3*	Multi-Family Dwellings (Apartments/ Condos)
Apartment House And Commercial Store		
Condominium		
Co-Op Units		
Dwelling Unit Plus Apartments		
Dwelling Units Plus Flats - One Parcel		
Flat Plus Apartment On One Parcel		
Flat Plus Store		
Flats And Duplex		
Live-In Studios		
Time Share		
Two Dwelling Units On One Parcel		
First Class Hotel	RES4	Temporary Lodging (Hotel/Motel)
Hotel		
Hotel Plus Commercial Units		
Motels		
Convalescent Homes, Nursing Homes	RES6	Nursing Homes
Commercial Store	COM1	Retail Trade (Stores)
Commercial Stores/Condominium		
Shopping Center		
Gas Stations	COM3	Personal/ Repair Services (Service Station/Shop)
Office - Condominium	COM4	Professional/ Technical Services (Offices)
Office And Commercial		
Office Buildings		
Banks	COM5	Banks
Hospitals	COM6	Hospital
Clubs, Lodges, Fraternal Organizations	COM8	Entertainment & Recreation (Restaurants/ Bars)
Golf Course		
Theatres	COM9	Theaters
Commercial Garage	COM10	Parking (Garages)
Parking Lot		
Parking Stall Condominium		

Table 5.3. Association of Assessor Use Codes with HAZUS®99 Occupancy Classes for San Francisco City/County (continued)

San Francisco County Assessor's Use Code	HAZUS®99 Occupancy Class	HAZUS®99 Occupancy Class Description
Industrial	IND1, IND2, IND3, IND4, IND5, IND6	Heavy Industrial, Light Industrial, Food/Drugs/ Chemicals, Metals/Minerals Processing, High Technology, Construction
Industrial Warehouse	IND2	Light Industrial
Churches, Convents, Rectories Or Welfare	REL1	Church/Non-Profit
Public Property And Buildings	GOV1	Government General Services (Office)
Schools	EDU1	Grade Schools
Total		

* Note: in HAZUS®99, RES3 was a single occupancy. In HAZUS®MH, RES3 is broken down into 6 subcategories.

Table 5.4. Distribution of Industrial Occupancy Square Footage from the HAZUS®99 Default Inventory Database

HAZUS®99 Occupancy Class		Percent of Total Industrial Square Footage
IND1	Heavy Industrial	12%
IND2	Light Industrial	44%
IND3	Food/Drugs/ Chemicals	13%
IND4	Metals/Mineral Processing	2%
IND5	High Technology	1%
IND6	Construction (Offices)	28%
Total		100%

5.2.2.2 Lessons Learned: Replacing the HAZUS®MH Default Occupancy – Square Footage Table

Lesson Learned: Use of assessor's data should provide more realistic estimates of exposed building square footage for most occupancies, but limitations associated with non-taxable properties may require the user to make use of HAZUS®MH default data for selected occupancy classes.

As part of the current Phase Two "Data Standardization" Project Pilot Studies, 2006 Assessor's data for Los Angeles County was pre-processed for use in HAZUS®MH. This database included more than 2 million parcel records. Each parcel record contains information on up to five buildings per parcel, and includes data on the use or occupancy of the property, building square footage, generalized construction type of the improvement, year built, and in some cases, number of stories. The records include detailed usage or occupancy information that allowed association of each Assessor use category with the equivalent HAZUS®MH occupancy class (e.g., office buildings may be mapped into HAZUS®MH class COM4. See also Section 5.2.1.1). The aggregated data included more than 6.4 billion square feet of taxable building exposure, distributed among the 33 uses, and is summarized in Table 5.5.

As noted above, the default square footage building inventory data within HAZUS®MH MR-1 was developed from 2000 census data for residential exposure, and from Dun & Bradstreet business data for non-residential exposure. This data is "proxy" data – for example, for residential uses, assumptions regarding square footage per housing unit were used to estimate building stock exposure from available census data. Table 5.5 also provides a summary of the HAZUS®MH MR-1 default square footage data for Los Angeles County by occupancy.

One significant limitation of the Assessor's database is the lack of data on non-taxable parcels, such as government buildings. In addition, prior to 1980, mobile homes were taxed as vehicles in California[9], and will therefore be underrepresented in the Assessor's database. To make up for these deficiencies, the user should consider combining Assessor's data for well-represented occupancies, with default data for the remaining classes, such as RES2, RES5, GOV1 and GOV2 in the current example.

As shown, the HAZUS®MH MR-1 default data ***underestimates*** the county-wide total amount of building square footage by 13.5%, relative to the Assessor's data. Table 5-6 breaks these figures down by general occupancy, revealing that, when compared to the Assessor's data, HAZUS®MH MR-1 slightly overestimates residential exposure, but significantly underestimates commercial and industrial exposure.

9 See: http://www.lacountyassessor.com/extranet/overview/mobhome.aspx

Table 5.5. Comparison of HAZUS®MH MR-1 Default Occupancy Square Footage Data to Custom Inventory Data Derived from County Assessor Data – County of Los Angeles (thousands of square feet)

Occupancy	Los Angeles County Assessor Data	HAZUS®MH MR-1 Default Data
	Total SQ FT (1000 SF)	Total SQ FT (1000 SF)
RES1	2,360,982	3,080,137
RES2	7,539	56,708
RES3A	207,925	134,425
RES3B	227,682	148,372
RES3C	300,019	215,145
RES3D	271,508	197,288
RES3E	317,122	202,309
RES3F	311,486	188,578
RES4	66,265	23,303
RES5	0	93,446
RES6	29,641	6,222
RES sub-total	***4,100,169***	***4,345,933***
COM1	464,140	200,849
COM2	498,381	186,838
COM3	57,637	91,563
COM4	390,309	274,970
COM5	14,140	10,205
COM6	37,576	18,027
COM7	18,340	41,708
COM8	41,614	68,437
COM9	5,047	2,638
COM10	138,391	0
COM sub-total	***1,665,575***	***895,235***
IND1	105,706	80,653
IND2	393,480	92,293
IND3	28,983	24,383
IND4	7,599	9,530
IND5	0	2,733
IND6	0	30,492
IND sub-total	***535,768***	***240,084***
AGR1	2,343	6,403
REL1	77,803	32,664
GOV1	1,997	6,625
GOV2	70	1,247
EDU1	25,479	19,366
EDU2	15,004	10,532
Total	***6,424,208***	***5,558,089***

Table 5.6. Difference between Los Angeles County Assessor's Data & HAZUS®MH MR-1 Default Data

General Occupancy	Difference Between Assessor's Data And HAZUS®MH MR-1 Default Data (Relative to Assessor's Data)	
	Number of Buildings	Square Footage
Residential	18%	6%
Commercial	-68%	-46%
Industrial	-81%	-55%
All Occupancies	10%	-13%

5.2.2.3 Lessons Learned: Replacing the HAZUS®MH Default Occupancy – Square Footage Table - Issues Associated with Condominiums

Lesson Learned: Condominium parcel data requires special attention when processing Assessor's data for use in HAZUS®MH. Because condominium units are treated as separate parcels in the Assessor's roll, data review and aggregation into approximate "buildings" is required. Aggregation may be performed manually or automatically, depending on the number of records and the resources available.

Within Assessor's databases, each condominium unit within a building is assessed individually, and therefore appears in the database as a separate parcel record. While direct aggregation of condominium square footage would introduce no errors in the overall census tract-based aggregated square footage data, the categorization into appropriate RES3 subclasses would be problematic (RES3 subclasses are defined by the total number of units), and would introduce errors into the estimated building counts by occupancy. Therefore, these parcels need to be aggregated into approximate "buildings", by occupancy.

The issue is relevant for both small counties and large ones. For example, in the two Phase Two Data Standardization Project Pilot Communities, San Luis Obispo County has about 4200 condominium parcels, while in Los Angeles County there are more than 300,000 condominium records. Depending on the number of records, automatic or manual aggregation approaches may be appropriate. Because some parcels will have invalid use codes or other data inconsistencies, not all units will be aggregated into buildings, but the net loss of building square footage is generally small.

For the San Luis Obispo County Phase Two Data Standardization Project Pilot Test, because of the relatively small number of parcels, aggregation was accomplished manually, by reviewing data for similarities in address, unit labeling, use, year built, construction type, and other fields, and aggregating accordingly. In Los Angeles County, the large number of condominium records meant that manual review and aggregation were not feasible. Instead, automated aggregation was utilized. Assessor's data for all condominium records were extracted into a separate table, and were aggregated into "buildings" by grouping records with equal values of the following parameters:

- Usecode
- Basic construction material (leftmost character in the quality class field)
- Decade built (left three characters of the year built field, stored as text)
- Left 3 characters of the house number (the house number is stored as 5 character text, so grouping on the left 3 characters would group all buildings in the same span of 100 together, e.g., records with house numbers "08475", "08477" and "08481" would have left 3 characters of "084" and would be grouped together).
- Street name
- Left/Right - Product of geocoding process, provides an indication as to whether property is on the left or right side of the street
- Zip code
- Census tract

For both pilot tests, more than 90% of condominium square footage was successfully aggregated into "buildings" which were then classified into HAZUS occupancies based on the aggregated number of units. These figures are summarized in Table 5-7.

Table 5.7. Difference between Los Angeles County Assessor's Data & HAZUS®MH MR-1 Default Data

County	Raw Assessor's Data for Condominiums		Aggregated Condominium Data	
	Number of Parcels	Total Square Footage	Resulting Number of "Buildings"	Total Square Footage (% of raw)
San Luis Obispo	4205	4,715,593	363	4,345,252 (92%)
Los Angeles	306,585	436,368,080	20,541	431,440,430 (99%)

5.2.3 Update #3: Updating the General Mapping Scheme through the HAZUS®MH GUI Using Assessor's Data on Construction Class

Construction class data (typically defined in terms of fire resistivity, and defined here in Table 5-8), is often available within Assessor's databases. This data may be used to develop a community-specific general mapping scheme, which provides the percent construction by occupancy by general construction type, e.g., wood, concrete, steel, masonry, manufactured housing.

Table 5.8. Construction Class Definitions Typically Used by Assessors

Construction Class Code	Construction Class Description
A	Fireproofed Structural Steel Frame
B	Fireproofed Reinforced Concrete Frame (formed or precast)
C	Buildings with noncombustible exterior walls, such as masonry bearing wall or poured-in-place concrete (e.g., tilt-up) construction
D	Wood (or Steel Stud) Framed Exterior Walls
S	Metal Frame and Walls (prefabricated). Sometimes represents "Special" structures (do not fit into other categories).
M	Sometimes used for Manufactured Housing

It should be noted that Construction Class "C" generally includes both masonry bearing wall and concrete tilt-up structures, the latter of which are considered "Concrete" in HAZUS®MH. Without additional information on prevalence of each construction type (for example, it might be assumed that industrial occupancies built before 1950 are unlikely to be tilt-up, and would be assumed to be masonry), it would be difficult to accurately disaggregate this data into its masonry and concrete components. As this is the only class that includes Masonry, the reasonable assumption is to classify all "C" buildings as Masonry, even though this may lead to an overestimation of the amount of masonry construction, and an underestimation of the amount of concrete construction. Further, classifying the whole group as Concrete would overestimate the exposure of all types of concrete construction, not just tilt-up, which is just one of several concrete classes. Accordingly, the assumption of "C" as Masonry is recommended for most users.

Data required to perform this update include:

- Building occupancy information.
- Square footage data.
- Construction class data.

The basic steps required to implement this update are as follows:

1. Ensure that for each building, data from the Assessor on occupancy, square footage and construction class are readily available in database format ("Assessor's data").
2. As discussed in Section 5.2.2, associate each detailed assessor's occupancy class with one of the 33 HAZUS®MH occupancy classes.
3. For each occupancy, aggregate building square footage by construction class, and develop a distribution (in terms of % of building square footage by construction type for "Wood", "Concrete", "Steel", "Masonry", and "Manufactured Housing").
4. Use the distribution to update the general mapping scheme data through the GUI as follows: Access the general occupancy mapping data tables through

the HAZUS®MH MR-1 GUI using the "Inventory", "General Building Stock", "Occupancy Mapping" menu selections. Select a mapping scheme from the list, right click for the context menu, and select "New…" to create a duplicate general "Mapping Scheme" for editing. Enter a name and description (optional) for the new general mapping scheme, and click "Create". HAZUS®MH will then ask you "Do you want to edit the newly created mapping scheme? (Y/N)". Click "Yes" to bring up a view of the general mapping scheme for editing. For each occupancy where you have sufficient data, edit the general construction type cell entries by double-clicking and entering the new values in percent expressed as whole integers (e.g., 80% would be entered as "80"). The distribution across the construction types for each occupancy must sum to 100. When all edits are completed, click "OK" to save your updated scheme.

5. To assign the newly created general mapping scheme to census tracts in your study region, right click to access the context menu, and click "Assign…" from the "Occupancy Mapping" dialog box. This will bring up the "Occupancy Mapping – Assign" dialog box, listing each census tract, and the currently assigned mapping scheme. From the list on the left hand side of the dialog box titled "Census tracts in the region:", select all the census tracts that are assigned to the default mapping scheme by holding down the left mouse button and scrolling to the bottom of the list. Under "Available mapping schemes:" on the right hand side of the dialog box, click on the name of the newly updated mapping scheme. Click "< Assign" to assign the new mapping scheme to each tract. The "Census tracts in the region:" list should now show the name of the updated mapping scheme. Click "OK" to continue. The "Occupancy Mapping" dialog will now show that the selected census tracts have been reassigned to the new mapping scheme. Close the dialog box by clicking the red "X" in the upper right hand corner, or by selecting "Close" from the menu accessed by clicking in the upper left hand corner of the dialog box. HAZUS®MH will now recalculate the building inventory tables stored by model building type, using the updated general mapping scheme.

5.2.3.1 Lessons Learned: Developing Community-Specific General Mapping Schemes

Lesson Learned: General mapping schemes developed from Construction Class data will reflect the limitations of the underlying Assessor's data. Users need to be aware of these limitations, especially with respect to data requirements of HAZUS®MH. Even if there is no exposure data (e.g., square footage data) for a given occupancy, the general mapping scheme must be provided in HAZUS®MH, and the distribution must sum to 100%. In these cases, it is recommended that the user update default mapping scheme data with Assessor's-based data for all occupancies with non-zero square footage, and leave the default mapping scheme data unchanged for remaining occupancies.

As part of the current Phase Two Data Standardization Project Pilot Tests for San Luis Obispo and Los Angeles Counties, replacement general mapping schemes were developed from Assessor's data. The default general mapping scheme applicable to both Los Angeles and San Luis Obispo Counties is given in Table 5-9; community-specific

mapping schemes generated from Assessor's data are given in Table 5-10 for Los Angeles County, and Table 5-11 for San Luis Obispo County. In both counties, it appears that there is more wood-frame residential construction than assumed in the HAZUS default, and less steel frame industrial construction. The user should keep in mind the potential overestimate of masonry and underestimate of concrete as discussed in Section 5.2.3.

In each county, there are several occupancies for which an updated general mapping scheme distribution could not be developed; RES5, IND5 and IND6 in Los Angeles County, and COM6, COM10, IND5, IND6, GOV2, and EDU2 in San Luis Obispo County. For these occupancies, users should maintain the HAZUS®MH MR-1 default mapping scheme distribution, as all distributions must sum to 100 for the software to operate properly. Further, data limitations associated with mobile homes suggest that, at least in Los Angeles County, the user keep the default general mapping scheme distribution for RES2.

Table 5.9. Default HAZUS®MH General Mapping Scheme Applicable to Both Los Angeles and San Luis Obispo Counties

Occupancy	Total	Wood %	Concrete %	Steel %	Masonry %	MH %
RES1	100	99	0	0	1	0
RES2	100	0	0	0	0	100
RES3A	100	78	8	5	9	0
RES3B	100	78	8	5	9	0
RES3C	100	78	8	5	9	0
RES3D	100	78	8	5	9	0
RES3E	100	78	8	5	9	0
RES3F	100	78	8	5	9	0
RES4	100	53	17	8	22	0
RES5	100	35	29	14	22	0
RES6	100	66	13	0	21	0
COM1	100	26	37	13	24	0
COM2	100	8	58	12	22	0
COM3	100	13	42	10	35	0
COM4	100	35	30	9	26	0
COM5	100	35	30	9	26	0
COM6	100	32	27	18	23	0
COM7	100	47	12	21	20	0
COM8	100	4	22	35	39	0
COM9	100	5	16	47	32	0
COM10	100	0	68	22	10	0
IND1	100	10	25	52	12	1
IND2	100	3	54	31	12	0
IND3	100	2	47	33	18	0
IND4	100	1	30	53	16	0
IND5	100	1	55	25	18	1
IND6	100	30	30	21	14	5
AGR1	100	40	15	27	16	2
REL1	100	22	30	22	26	0
GOV1	100	8	38	29	25	0
GOV2	100	39	18	33	10	0
EDU1	100	23	23	24	30	0
EDU2	100	5	24	27	44	0

Table 5.10. HAZUS®MH General Mapping Scheme Developed from Los Angeles County Assessor's Data

Occupancy	Total	Wood %	Concrete %	Steel %	Masonry %	MH %
RES1	100	100	0	0	0	0
RES2*	**100**	**44**	**0**	**0**	**1**	**55**
RES3A	100	100	0	0	0	0
RES3B	100	100	0	0	0	0
RES3C	100	100	0	0	0	0
RES3D	100	99	0	0	1	0
RES3E	100	96	0	0	4	0
RES3F	100	88	6	3	3	0
RES4	100	43	34	9	14	0
RES5	***0***	***0***	***0***	***0***	***0***	***0***
RES6	100	66	14	3	17	0
COM1	100	35	6	6	53	0
COM2	100	15	2	1	82	0
COM3	100	31	2	1	66	0
COM4	100	18	19	40	23	0
COM5	100	24	17	17	42	0
COM6	100	17	37	32	14	0
COM7	100	31	22	23	24	0
COM8	100	51	4	4	41	0
COM9	100	10	18	22	50	0
COM10	100	45	35	2	18	0
IND1	100	23	4	7	66	0
IND2	100	17	1	1	81	0
IND3	100	26	4	2	68	0
IND4	100	43	8	1	48	0
IND5	***0***	***0***	***0***	***0***	***0***	***0***
IND6	***0***	***0***	***0***	***0***	***0***	***0***
AGR1	100	69	0	1	30	0
REL1	100	61	5	3	31	0
GOV1	100	44	11	0	45	0
GOV2	100	57	0	0	43	0
EDU1	100	51	5	3	41	0
EDU2	100	22	33	12	33	0

* The general mapping scheme distribution for RES2 is not recommended for use due to significant data limitations.

Table 5.11. HAZUS®MH General Mapping Scheme Developed from San Luis Obispo County Assessor's Data

Occupancy	Total	Wood %	Concrete %	Steel %	Masonry %	MH %
RES1	100	98	0	0	1	1
RES2	100	4	1	0	0	95
RES3A	100	99	0	0	1	0
RES3B	100	98	0	0	1	1
RES3C	100	99	0	1	0	0
RES3D	100	100	0	0	0	0
RES3E	100	100	0	0	0	0
RES3F	100	100	0	0	0	0
RES4	100	96	0	0	4	0
RES5	100	96	0	0	4	0
RES6	100	100	0	0	0	0
COM1	100	42	0	1	57	0
COM2	100	44	0	3	45	8
COM3	100	47	0	5	47	1
COM4	100	98	0	0	2	0
COM5	100	57	0	0	43	0
COM6	***0***	***0***	***0***	***0***	***0***	***0***
COM7	100	85	0	0	15	0
COM8	100	54	1	2	42	1
COM9	100	28	0	0	72	0
COM10	***0***	***0***	***0***	***0***	***0***	***0***
IND1	100	100	0	0	0	0
IND2	100	51	0	0	46	3
IND3	100	39	0	0	59	2
IND4	100	79	0	0	0	21
IND5	***0***	***0***	***0***	***0***	***0***	***0***
IND6	***0***	***0***	***0***	***0***	***0***	***0***
AGR1	100	75	0	0	2	23
REL1	100	97	0	0	3	0
GOV1	100	84	0	0	10	6
GOV2	***0***	***0***	***0***	***0***	***0***	***0***
EDU1	100	75	0	0	25	0
EDU2	***0***	***0***	***0***	***0***	***0***	***0***

5.2.4 Update #4: Updating the Census Tract-Based Building Count Table from Assessor's Data (Level 2 Updates Using BIRT)

This update is similar in nature to Update #2 - updating the census tract-based "square footage – occupancy" table from assessor's data. In practice, the two updates would likely be performed at the same time. One particular issues of concern to both updates is the aggregation of condominium parcels (discussed in Section 5.2.1.3).

Data required to perform this update include:

- Building occupancy information – generally available in Assessor's databases.
- Census tract location for each building/parcel – often available from County Planning or GIS Departments.

The basic steps required to implement this update are as follows:

1. Ensure that for each building, data from the Assessor on occupancy is readily available in database format ("Assessor's data").
2. Associate each detailed assessor's occupancy class with one of the 33 HAZUS®MH occupancy classes. (See Section 5.2.2 for a detailed discussion.)
3. For each building or parcel, obtain the latitude and longitude data from the County Planning or GIS department. Have a GIS Analyst overlay the lat/long locations of all buildings onto maps of 2000 census tract boundaries, and build a table ("Parcel – Census Tract") listing each parcel number or building identifier and its associated census tract identifier.
4. Within a database program (such as Microsoft Access), link the "Assessor's data", "Occupancy key", and "Parcel-Census Tract" tables, and aggregate building counts by HAZUS®MH occupancy class for each census tract.
5. Following the building count table template provided with BIRT ("ASSR_Template.MDB"), reformat as required.

5.2.5 Update #5: Use the HAZUS®MH MR-1 AEBM to Analyze URM Structures on a Building-by-building Basis

Using the HAZUS®MH MR-1 Advanced Engineering Building Module (AEBM) for selected structure types for which detailed data are readily available is recommended for the more vulnerable building types. Specifically, using the AEBM for URM buildings is recommended because 1) local jurisdictions are likely to have inventory data, as a catalog is required by the California Seismic Safety Commission, 2) additional data collection efforts are expected to be limited (e.g., the user will need, at a minimum, occupancy and square footage data, and can estimate remaining required parameters), and 3) these structures are considered collapse and life-safety hazards when not mitigated.

Data required to perform this update include:

- Inventory data for URM structures, including building square footage, number of stories, number of daytime & nighttime occupants, and replacement cost (although this can be estimated using the standard HAZUS replacement cost model)
- Location data for URM structures, in Lat/Long

The basic steps required to implement this update are as follows:

1. Collect required building inventory data for each URM structure in the community, including geocoded location.
2. Access the HAZUS®MH MR-1 AEBM Profiles input screen from the "Inventory", "AEBM", "Profiles" menu options. Create a separate profile for each occupancy type for which your community has URM buildings, including separate profiles reflecting building of different heights and quality levels, as described in the following discussion. Building type should be either "URML" for low-rise-structures, or "URMM" for mid-rise structures. Seismic design level for URM structures should always be "Low", since URM structures were generally constructed prior to 1933, when seismic design criteria were limited. Building Quality for typical URM buildings should be "Code" level, while mitigated structures can be assessed by modeling them as "Superior" Quality Level.
3. Access the HAZUS®MH MR-1 AEBM Inventory input screen from the "Inventory", "AEBM", "Inventory" menu options. Right click for the context menu, and select "Start Editing" to add data. If the number of records is small, right click and select "Add record" to add records one at a time. Enter data on building location (lat/long), square footage, and number of occupants, if available. Enter the associated profile name, as discussed above. If the number of records is large, right click and select "Import" to import a database file. (The user is referred to the HAZUS®MH MR-1 AEBM User's Manual for detailed instructions).
4. Once the profiles and inventory data are entered into HAZUS, loss estimates can be generated in a manner similar to other HAZUS loss estimates by selecting "Advanced Engineering Building Model" from the "Analysis", "Run" menu.

5.2.6 Update #6: Updating the Occupancy Mapping Scheme with Better Height Data Using the MaSC Tool

The specific mapping schemes within HAZUS®MH provide the distribution, within each general construction type (e.g., Steel), of construction across the detailed structural classes (e.g., S1L, S1M, S1H, S2L, S2M, S2H, S3, S4L, S4M, S4H, S5L, S5M, and S5H). See Table 2-5 for a full listing of specific model building types used in HAZUS®MH. The default mapping schemes provided with HAZUS®MH MR-1 assume all construction is low-rise. That is, the percent of construction attributed to mid- and high-rise structures is always 0%. While this may be an adequate assumption in rural counties with small or no urban cores, it is unrealistic in highly urbanized areas such as the San Francisco Bay area and Los Angeles.

The user has several options for modifying the specific mapping schemes. One is to use one mapping scheme for the whole study area, and adjust individual model building type distributions to reflect the proportion of mid- and high-rise buildings throughout the study area. Another is to utilize two mapping schemes; use the default mapping schemes as is in areas outside the highly urbanized core, and build a modified mapping scheme in areas of significant mid- and high-rise construction. In either case, the user will need to edit the mapping scheme files. Instructions for these modifications are provided below.

Data required to perform this update include:

- Identification of the census tracts to which the modified mapping scheme should be applied (e.g., a list of census tracts in the downtown area).
- Information on the proportion of construction that is low-, mid- and high-rise, by structure type (i.e., distribution of building height by structure type). This data may be derived from Assessor's data, although not all Assessor's databases contain height information. When available, this information is likely to be associated with basic structure types (e.g., "steel"), so the resulting distributions would best be applied to all HAZUS®MH model building types of that material.
- To make the best use of Assessor's data, the subset of data within the census tracts of interest should be used to develop the distribution. This would require obtaining the latitude and longitude for each building in the area, and the associated census tract (see Section 5.2.1). Using the relevant subset of data is key, because county-wide statistics may not be very informative. For example, the height distribution developed from Los Angeles County Assessor's data yields a county-wide height distribution (based on building square footage) of 97% low-rise, 1% mid-rise, and 2% high-rise. While this may be an accurate aggregate representation of the county as a whole, it would not be a reasonable depiction of downtown Los Angeles.
- Alternatively, the height distribution data may be developed by doing limited field surveys. If engineers are available to perform the surveys, the distributions can be developed by basic or detailed structure type, and applied accordingly. If surveys are to be performed by non-engineers or others who may not be able to determine construction type, generic distributions can be developed to apply to all structure types within the geographic area of interest. This approach is recommended when the area of interest is small, and when aggregate data is not particularly instructive.

The basic steps required to implement this update are as follows:

1. Develop a height distribution by detailed or basic structure type, or for all structure types as discussed above.
2. Edit the default HAZUS®99 mapping scheme data provided with the MaSC tool to reflect the newly developed height distribution as follows: The HAZUS®99 mapping scheme data provided with the MaSC tool is the default mapping scheme for areas designated as "high" seismic zones in California. This mapping scheme is designated "DFLT06H" where "H" (for High) designates the

underlying seismic zone. Mapping scheme data is stored in three .DBF files, named "DFLT06H.HGB" (stores data on the distribution for high seismic design level, all qualities), "DFLT06H.MGB" (moderate seismic design level), and "DFLT06H.LGB" (low seismic design level). Other default mapping schemes are also available for California, including DFLT06M (moderate seismic zone), and DFLT06L (low seismic zone). Rename the three data files with a .DBF extension and a descriptive name (e.g., down_hgb.dbf for downtown area) for import into Microsoft Access (preferred method of editing). The files are laid out as follows: occupancy, total (represents the total percent of construction at the current design level for that occupancy), a block of 36 columns with the prefix "T" (for typical or code quality) followed by the model building type designation (e.g., TW1 = typical quality wood light frame), a second block of 36 columns with the prefix "P" (for poor or inferior quality), a third block of 36 columns with the prefix "S" (for superior quality), and a final block of 36 columns with the prefix "_" used to present subtotals by model building type across all three quality classes. The user can now redistribute construction currently assumed to be low-rise across low-, mid- and high-rise construction. For example, the default moderate seismic design level mapping scheme (table named down_mgb in our example) indicates that 7% of offices (COM4) are classified as C2L (low-rise concrete shear wall buildings). Based on Assessor data or surveys, the user may know that concrete office buildings in the area of interest are actually 30% low-rise, 60% mid-rise and 10% high-rise. To reflect this, the user would make the following edits: TC2L would be changed from 7 to 2 (0.3 * 7), TC2M would be changed from 0 to 4, and TC2H would be changed from 0 to 1. Similarly, the totals columns (_C2L, _C2M, and _C2H) would also require the same changes. The user should ensure that the final distribution for any model building type that has been adjusted adds to the same total as the original distribution. Further, the user must also remember that every change in exposure for an individual quality level must be reflected in the totals columns.

3. Once all height adjustments have been made, the user should export the Access tables, and rename according to the HAZUS®99 convention. For example, the edited downtown mapping schemes exported from Access as "downhgb2.dbf" could be renamed "downtwn2.HGB", etc.
4. The user can then operate the MaSC tool to "post" the updated mapping schemes into a given study region's SQL server database, for access within HAZUS®MH. See Appendix B for more information on using the MaSC tool.
5. To assign the new downtown mapping scheme to some or all of the census tracts within the study region, follow the instructions in Section 5.2.3 ("*Update #3: Updating the General Mapping Scheme Through the HAZUS®MH GUI Using Assessor's Data on Construction Class")*, Step 5.

This same modification process can be used to alter the distribution across seismic design levels (based on expert opinion or age data), although the book-keeping here is more complex, as changes are not limited to one mapping scheme table at a time.

5.2.7 Update #7: Updating the Specific Occupancy Mapping Schemes to Reflect the Distribution of Specific Structure Types

This update can be performed in two ways: using the MaSC Tool or directly through the HAZUS®MH MR-1 GUI.

While detailed data allowing a building-by-building determination of specific model building type for all structures in an area would be difficult to develop, data do exist to allow improved characterization of selected model building types. For example, all jurisdictions in California are required to have surveyed their unreinforced masonry (URM) buildings. Data required to make use of this type of survey in HAZUS®MH include occupancy and building square footage. When the user knows that URMs of a certain occupancy exist, to make use of that data in HAZUS®MH MR-1, the user must either determine what percent of all structures of the particular occupancy the URMs represent (if using the MaSC Tool) or determine what percent of all *masonry* structures of the particular occupancy the URMs represent. The difference here is subtle, but important. For example, if several URM hotels are identified, to use the MaSC, the user only needs to know the total square footage of all hotels (to determine the percent that are URM). To make a similar change through the HAZUS®MH MR-1 GUI, the user needs to know the total square footage of masonry hotels, in order to estimate the percent of masonry hotels that are URM.

In either scenario, this data could be included in a HAZUS®MH analysis by creating custom mapping schemes for census tracts known to have URMs (following the basic process laid out in Section 5.2.6), or by using aggregate statistics to modify a region-wide mapping scheme.

Similarly, prior research (i.e., the SAC Steel project) has identified building type distributions intended to reflect the distribution of steel moment resisting frame (SMRF) structures, found to be vulnerable to damage in the 1994 Northridge earthquake (see Section 5.2.7.1).

When available, Assessor's data can be used to replace default mapping schemes, using structural engineering expert opinion to develop inference algorithms to associate basic structure type, age, occupancies and height, with specific model building types. From the Assessor's data, the user would determine total square footage by basic structure type, height (if available) and age (if available). A structural engineer would then be called upon to suggest how the total square footage by occupancy by basic structural type should best be distributed among the specific model building types. For example, industrial buildings classified by the Assessor as "masonry" could either be HAZUS®MH model building type PC1 or RM1[10] (although those built before 1933 can also be URM), while buildings classified by the Assessor as "concrete" industrial buildings are likely to be C3 or C2 when low-rise, and C2 when mid-rise (although mid-rise industrial buildings are more rare). "Steel" industrial buildings are expected to be either S4 or S5.

[10] See Table 2.5 for HAZUS®MH model building type definitions.

Data required to perform a mapping scheme update related to model building type adjustments include:

- Detailed data on a particular type of building, such as URM, including occupancy, census tract location, and square footage. For each occupancy, an estimate of total square footage of buildings in the area of interest should also be known. If possible, this total should be broken down by construction class to facilitate updates through the HAZUS®MH MR-1 GUI.
- When occupancy, basic structure type, age and height is available, a structural engineer can develop an detailed, data-specific relationship to specific model building type based on knowledge of local construction patterns.

The basic steps required to implement this update are as follows:

1. Identify specific building types of concern in your study area. Collect available data from the Assessor or the Building Department.
2. Using structural engineering expert opinion, determine adjusted mapping scheme percentages. (See Section 5.2.7.1 for an example).
3. Modify the mapping schemes using the MaSC (see Section 5.2.6) or through the HAZUS®MH MR-1 GUI (see Section 5.2.3).

5.2.7.1 Lessons Learned: Updating Occupancy Mapping Schemes to Better Represent Specific Vulnerable Building Types

Lesson Learned: Assessor's data, supplemented with expert structural engineering judgment, may be used to modify default occupancy-mapping schemes to reflect exposure of vulnerable structure types, but the process can be complicated and time-consuming.

As part of a study for the SAC Steel project to estimate the benefits of implementing new seismic design criteria for welded steel frame buildings, EQE International utilized HAZUS®99 to estimate losses (and losses avoided resulting from code implementation) within the City of Los Angeles (EQE,2000). A "Level 2" HAZUS®99 analysis was performed; changes to the HAZUS® default data included development of customized building inventories and mapping schemes, replacement of default cost data and use of custom steel moment-resisting frame (SMRF) fragility curves. Although this analysis was performed using HAZUS®99, the lessons learned are applicable to HAZUS®MH MR-1 as well.

Within HAZUS®, specific occupancy to model building type "mapping schemes" provide a distribution of square footage among the 36 model building types (e.g., steel moment frame structure, concrete shear wall structures, etc.) for each use or occupancy. In addition, the occupancy-mapping schemes further divide the model building types into 9 variations relative to three (3) seismic design levels (low-, moderate- and high-seismic design) and three (3) building qualities (code, pre-code/inferior, and superior), resulting in 324 model building type variations. Mapping scheme data for each seismic design level is stored in a separate file. Collectively, these three files represent the complete mapping scheme. Each file has four data blocks, one block for each quality level (three total) tabulating the square footage distribution by occupancy and model building type, and one tabulating design level sub-totals.

Default mapping schemes are provided in the HAZUS® Technical Manual, and also within the software, differentiated by region (e.g., east coast, mid-west and west coast). In general, building quality and seismic design level may be roughly determined by construction date, relative to changes in building codes. For example, in UBC seismic zone 4 (applicable to California), the suggested age categorization schemes (NIBS, 2002, p. 5-71) are; pre-1941 (low seismic design level, inferior/pre-code quality), 1941 – 1975 (moderate seismic design level, code quality), and Post-1975 (high seismic design level, code quality)[11]. For the SAC Steel Benefits study, these three sub-categories were utilized to represent the entire inventory (i.e., only 3 variations of each model building type were used). To develop the three required occupancy-mapping schemes data blocks, data from the Los Angeles County Assessor were utilized in conjunction with default distributions provided within HAZUS®99, as well as assumptions about SMRF structures developed from expert structural engineering judgment.

[11] This differs slightly from the default mapping schemes provided in the Technical Manuals and with the HAZUS®MH software, which utilize Pre-1950, 1950 – 1970, and post-1970 as age categories.

As mentioned previously, Assessor's databases often include generalized information on each improvement's construction. In Los Angeles County, five classes are differentiated, as follows:

- A = steel frame
- B = concrete frame
- C = brick, concrete block, "poured-in-place" concrete (including URM, reinforced masonry, tilt-ups, etc.)
- D = wood frame
- S = special, other

By age, these categories may be mapped into the general HAZUS® model building types. Some of the associations are more obvious than others (e.g. pre-1933 Class C structures are likely to be URM), but in some cases, there is no way to definitively assign generalized structure types into the detailed HAZUS® classes (e.g., "steel frame" could include HAZUS® steel moment frame (S1), steel braced frame (S2), steel light frame (S3), steel frame with CIP concrete shear walls (S4), or steel frame with URM infill walls (S5)). Therefore, a method for distributing generic assessor construction classes into detailed HAZUS® model building types was required.

As a starting point, citywide summaries for each occupancy category were generated, aggregating the Assessor's square footage data by age, general structure type, and height. As the approach was to combine actual Assessor's data and distributions from the HAZUS®99 default mapping schemes, the age groupings used in the default west-coast mapping schemes (Pre-1950, 1950 – 1970, and Post-1970) were utilized. The resulting data could then be associated with the three identified mapping scheme categories. For example, retail structures (COM1) were determined to be 24% "high seismic design level– code quality", 31% "moderate – code", and 45% "low – inferior". The data for each mapping scheme category were further broken down by height and structure class (e.g., for "low-inferior" COM1 structures, 43% is low-rise, distributed as follows: 2% Class A, 2% Class B, 23% Class C and 16% Class D).

To associate this information with the appropriate HAZUS® model building type sub-category and build the mapping scheme files, a two-step approach was taken: 1) distribute data into specific model building types directly when sufficient information exists, and 2) distribute the rest according to relative percentages provided in the HAZUS® default mapping schemes. Only a few building types were mapped directly – wood frame (Class D), URM and SMRF structures. Wood frame structures were mapped into W1 (light frame, less than or equal to 5,000 SF) or W2 (commercial and industrial, more than 5,000 SF), according to use. That is, single family residential structures (RES1) were mapped into W1, while multi-family and other residential structures (RES3, RES4, RES5, and RES6), as well as other non-residential uses were mapped into W2. Pre-1933 Class C structures were mapped into URM, and SMRF structures (the focus of this project) were mapped according to assumptions, described below, developed in conjunction with structural engineers as part of the project.

Based on expert opinion and available data, the following assumptions were used to determine the percent of Class A ("steel") construction in southern California[12] that was considered SMRF (S1):

- All "steel" structures (as classified by the Assessor) built prior to 1960 had a low likelihood of actually being SMRF. **20%** of the total square footage for these steel structures was assumed to be SMRF.
- Tall "steel" structures (5 or more stories) built after 1960 had a very high likelihood of being SMRF. **90%** of the total square footage for these steel structures was assumed to be SMRF.
- About half of short "steel" structures (4 stories or less) built after 1960 were deemed likely to be SMRF. **60%** of the total square footage for these steel structures was assumed to be SMRF.

To distribute the remaining square footage of steel and other structure types, the default HAZUS®99 west coast mapping scheme information was used[13]. The relative percentages for each construction material were used to distribute the actual percent of square footage. For example, from the Assessor's data we determine that there is more than 29 million square feet of "high seismic design –code quality", high-rise office buildings (COM4). This represents 25.6% of the total square footage for all offices, and consists of 22.9% Class A (steel frame) and 2.7% Class B (concrete frame). Our SMRF assumptions result in the assignment of 20.6% (90% of the Class A area) into S1H, leaving 2.3% constructed of other steel. The default west-coast mapping scheme for high-code, high-rise COM4 (as documented in Table 3A.10 in both the HAZUS®MH Technical Manual and the earlier HAZUS®99 Technical Manual) suggests the following overall distribution; 56% S1H, 10% S2H, 14% S4H, 14% C1H, 5% C2H, and 1% PC2H. To distribute the remaining 2.3% of the Class A square footage, the relative proportions of S2H and S4H are utilized[14], resulting in the assignment of 1.0% S2H, and 1.3% S4H. The 2.7% concrete frame was similarly distributed among HAZUS® classes C1H (1.9%), C2H (0.7%) and PC2H (0.1%)[15].

It should be noted that this method for developing custom mapping schemes is a time-intensive process. While the ideal representation of the building inventory might appear to be mapping schemes for each census tract or for smaller sections of the study area, the development of multiple mapping schemes can take a prohibitive amount of time, and may not be worth the effort. As part of the second HAZUS® pilot test, EQE International developed Level 2 building inventory files for the City of Boston, which has a total of 460 million square feet of exposure on just over 100,000 parcels. In a test of one city-wide mapping scheme versus 22 mapping schemes for sub-regions of the City, EQE found only a 5% change in building-related losses (EQE, 1996).

---

[12] These assumptions were developed for application in southern California; application beyond southern California may require expert structural engineering input and revision.
[13] This information was provided with the HAZUS®99 software, and was documented in Tables 3A.2 – 3A.10 in the HAZUS®99 Technical Manual (NIBS, 2002). Current versions are provided with the HAZUS®MH MR-1 software and are documented in Tables 3A.2 – 3A.10 of the HAZUS®MH MR-1 Technical Manual (DHS/FEMA, 2005).
[14] The relative proportion of S2H would be calculated as 10%/24% or 41.67%, while S4H would be 14%/24% or 58.33%.
[15] Note that within HAZUS®99, mapping scheme percentages are whole numbers without decimals, necessitating some rounding and redistribution to ensure overall totals add to 100 percent.

5.2.8 Update #8: Updating the Census Tract-Based "Square Footage – Occupancy" Table with BIRT Using Census Data Updates

The intent of this update is to allow a user without access to detailed building inventory data to better reflect recent growth and construction in the HAZUS®MH building inventory databases. A simple growth factor, derived from county level population data, can be used to increase building inventory exposure for single and multi-family residential structures (RES1 and RES3A-F). This assumes that residential building stock grows in proportion to population growth, which is a reasonable assumption for use in HAZUS®MH, given that the HAZUS®MH inventory data is derived from census data. Increasing building exposures for other occupancies is not recommended because 1) their growth tends to lag behind residential construction, so increasing them at the same rate as residential construction may not be appropriate, and 2) these residential occupancies (RES1 and RES3A-F) typically account for about two-thirds of the inventory. Further, it should be kept in mind that this approach increases building square footage for all census tracts within the County, while in reality, growth is likely to be concentrated in selected areas within the County.

Data required to perform this update include:

- Census Bureau estimates of population growth relative to the 2000 Census, e.g., population estimates for July 1, 2005 available by County at: http://www.census.gov/popest/counties/CO-EST2005-01.html
  This data is also provided in Table 5.5. For many counties, growth since 2000 is so small (e.g., less than 5%) that updating at this time would be deemed unnecessary. As time passes, the relevance of these updates will increase.

The basic steps required to implement this update are as follows:

1. Identify the county or counties represented in your study region.
2. From Table 5.12, find the growth factor applicable to each county of concern. Population growth since the 2000 census at the county level is as large as 28% (Placer County), with a net increase of 7% statewide. It should be noted that for counties with net population losses, no change to the building inventory is recommended.
3. Using the BIRT tool, make a copy of your study regions' default square footage occupancy table within Microsoft Access.
4. For each census tract, multiply the existing square footage value for RES1 and RES3A-F by the county growth factor. Treat this resulting table as Level 2 data within BIRT.
5. Using BIRT, post the updated square footage data into the Study Region, and use the BIRT models to update building count tables, as well as building and content exposure tables. (See Appendix C for more information on using BIRT.)

County level population estimates are made posted as they become available, and may be found at http://quickfacts.census.gov/qfd/states/06000.html . To make use of these data,

the user would 1) compute the increase in population for each county from the 2000 baseline, 2) determine the percent increase (relative to the 2000 baseline data), 3) multiply square footage exposure by a factor equal to 1.0 plus the percent increase.

Table 5.12. U.S. Census Bureau County Level Population Estimates for California and Suggested Inventory Increase Factors for Use in HAZUS®MH (see: http://www.census.gov/popest/counties/CO-EST2005-01.html)

FIPS County Code	County Name	July 1, 2005 Estimate	April 1, 2000 Estimates base	Numeric Population Change 2000-2005	Percent Population Change 2000-2005	Inventory Increase Factor for Use in HAZUS®MH
06	**California**	**36,132,147**	**33,871,653**	2,260,494	6.7%	1.07
06001	Alameda County	1,448,905	1,443,741	5,164	0.4%	1.00
06003	Alpine County	1,159	1,208	-49	-4.1%	no change recommended
06005	Amador County	38,471	35,100	3,371	9.6%	1.10
06007	Butte County	214,185	203,171	11,014	5.4%	1.05
06009	Calaveras County	46,871	40,554	6,317	15.6%	1.16
06011	Colusa County	21,095	18,804	2,291	12.2%	1.12
06013	Contra Costa County	1,017,787	948,816	68,971	7.3%	1.07
06015	Del Norte County	28,705	27,507	1,198	4.4%	1.04
06017	El Dorado County	176,841	156,299	20,542	13.1%	1.13
06019	Fresno County	877,584	799,407	78,177	9.8%	1.10
06021	Glenn County	27,759	26,453	1,306	4.9%	1.05
06023	Humboldt County	128,376	126,518	1,858	1.5%	1.01
06025	Imperial County	155,823	142,361	13,462	9.5%	1.09
06027	Inyo County	18,156	17,945	211	1.2%	1.01
06029	Kern County	756,825	661,653	95,172	14.4%	1.14
06031	Kings County	143,420	129,461	13,959	10.8%	1.11
06033	Lake County	65,147	58,309	6,838	11.7%	1.12
06035	Lassen County	34,751	33,828	923	2.7%	1.03
06037	Los Angeles County	9,935,475	9,519,330	416,145	4.4%	1.04
06039	Madera County	142,788	123,109	19,679	16.0%	1.16
06041	Marin County	246,960	247,289	-329	-0.1%	no change recommended
06043	Mariposa County	18,069	17,130	939	5.5%	1.05
06045	Mendocino County	88,161	86,265	1,896	2.2%	1.02
06047	Merced County	241,706	210,554	31,152	14.8%	1.15
06049	Modoc County	9,524	9,449	75	0.8%	1.01
06051	Mono County	12,509	12,853	-344	-2.7%	no change recommended
06053	Monterey County	412,104	401,762	10,342	2.6%	1.03
06055	Napa County	132,764	124,308	8,456	6.8%	1.07
06057	Nevada County	98,394	92,033	6,361	6.9%	1.07
06059	Orange County	2,988,072	2,846,289	141,783	5.0%	1.05
06061	Placer County	317,028	248,399	68,629	27.6%	1.28
06063	Plumas County	21,477	20,824	653	3.1%	1.03
06065	Riverside County	1,946,419	1,545,387	401,032	26.0%	1.26
06067	Sacramento County	1,363,482	1,223,499	139,983	11.4%	1.11
06069	San Benito County	55,936	53,234	2,702	5.1%	1.05

FIPS County Code	County Name	July 1, 2005 Estimate	April 1, 2000 Estimates base	Numeric Population Change 2000-2005	Percent Population Change 2000-2005	Inventory Increase Factor for Use in HAZUS®MH
06071	San Bernardino County	1,963,535	1,709,434	254,101	14.9%	1.15
06073	San Diego County	2,933,462	2,813,833	119,629	4.3%	1.04
06075	San Francisco County	739,426	776,733	-37,307	-4.8%	no change recommended
06077	San Joaquin County	664,116	563,598	100,518	17.8%	1.18
06079	San Luis Obispo County	255,478	246,681	8,797	3.6%	1.04
06081	San Mateo County	699,610	707,163	-7,553	-1.1%	no change recommended
06083	Santa Barbara County	400,762	399,347	1,415	0.4%	1.00
06085	Santa Clara County	1,699,052	1,682,585	16,467	1.0%	1.01
06087	Santa Cruz County	249,666	255,602	-5,936	-2.3%	no change recommended
06089	Shasta County	179,904	163,256	16,648	10.2%	1.10
06091	Sierra County	3,434	3,555	-121	-3.4%	no change recommended
06093	Siskiyou County	45,259	44,301	958	2.2%	1.02
06095	Solano County	411,593	394,513	17,080	4.3%	1.04
06097	Sonoma County	466,477	458,614	7,863	1.7%	1.02
06099	Stanislaus County	505,505	446,997	58,508	13.1%	1.13
06101	Sutter County	88,876	78,930	9,946	12.6%	1.13
06103	Tehama County	61,197	56,039	5,158	9.2%	1.09
06105	Trinity County	13,622	13,022	600	4.6%	1.05
06107	Tulare County	410,874	368,021	42,853	11.6%	1.12
06109	Tuolumne County	59,380	54,504	4,876	8.9%	1.09
06111	Ventura County	796,106	753,197	42,909	5.7%	1.06
06113	Yolo County	184,932	168,660	16,272	9.6%	1.10
06115	Yuba County	67,153	60,219	6,934	11.5%	1.12

6. Data Checking

The accuracy of HAZUS®MH loss estimates is largely dependent on the quality of the underlying data. As the user adjusts the default parameters for a specific study site or imports additional data, the accuracy of the estimates will generally increase, but not if the data is processed or interpreted incorrectly. Data checking is the process of verifying that the data are reasonable. This chapter presents a series of methods the user can use to check the data, such as reviewing, querying, mapping, and graphing both the results and the input data. In addition, this guide suggests methods to verify HAZUS®MH building inventory data (square footage, building count etc) updated through the BIRT program.

Although aspects of data processing are discussed, much of the process is qualitative, and managers or other decision makers will benefit from reviewing this chapter. It should be noted that data checking does not replace verifying the final HAZUS®MH loss estimate results, which is a skill that comes from years of experience reviewing actual losses from earthquakes. Before HAZUS®MH loss estimates are released to the public, they should be examined by loss estimation experts, particularly after an actual earthquake.

6.1 Data Review

When examining the data, erroneous data often stands out, and can aid the user in discovering larger issues. It may help to assume the input data are incorrect and to visualize the data in various ways to bring inconsistencies to light. For example, the units for replacement cost in HAZUS®MH are thousands of dollars, but a user could miss this detail. Having made this mistake, the user would not be looking for this problem, but by checking the default data and the updated values, the user should be able to detect that the values are off by a factor of a thousand. Spot-check values for accuracy and completeness by examining each database with the "info" tool in MapInfo or ArcGIS. Focus on a specific, well known area, as well as checking values throughout the study area.

Next, the user should review the metadata and attribute information. If data is downloaded from an online source, the user should contact someone involved in the data preparation. The user should make sure they understand why the data was initially prepared. Although GIS data is usually accompanied by metadata, it should not be assumed that the data is appropriate for use with HAZUS®MH. The user must review the raw data thoroughly. For example, are land values included in the replacement cost? Are the replacement values for the current year, or do they need to be adjusted? Is the square footage for the building footprint, or is total square footage being utilized? Does the square footage include the basement and the garage? Every field that is used must be examined to make sure that the intended use of the data is in agreement with what HAZUS®MH requires.

Data processing should also be reviewed. It is very easy for data to become corrupt or truncated in translation from such programs as Microsoft Excel or ArcView. Additionally, users may make mistakes during data processing. Initially, data processing is frequently an exploratory task, where each step may not be well defined. Preliminary documentation of SQL queries or other scripted data processing tasks can help form the basis for a review. It is important to reproduce all data processing tasks outside the primary data processing environment through hand calculations, a second software program, or by checking the data against an independent source. More than one person should check the data processing steps.

6.2 Mapping Data

Mapping often helps to visualize data qualitatively. Map or overlay the data with other layers from HAZUS®MH and with commercial databases of known accuracy/quality. Make sure the data are in the right state, county, and city. The density of essential facilities and infrastructure should correlate closely with population density. Most types of facilities should occur in every county and every major city within the study area. Check for connectivity between pipelines and transportation networks. Look for projection problems such as datum shifts. Spatial databases should be correlated; for example rail facilities should be along train tracks and major bridges should be along highways. Figure 6-1 below is a hypothetical illustration of poor data quality detected by overlaying bridge data onto highway data. In short, make sure the data makes sense geographically.

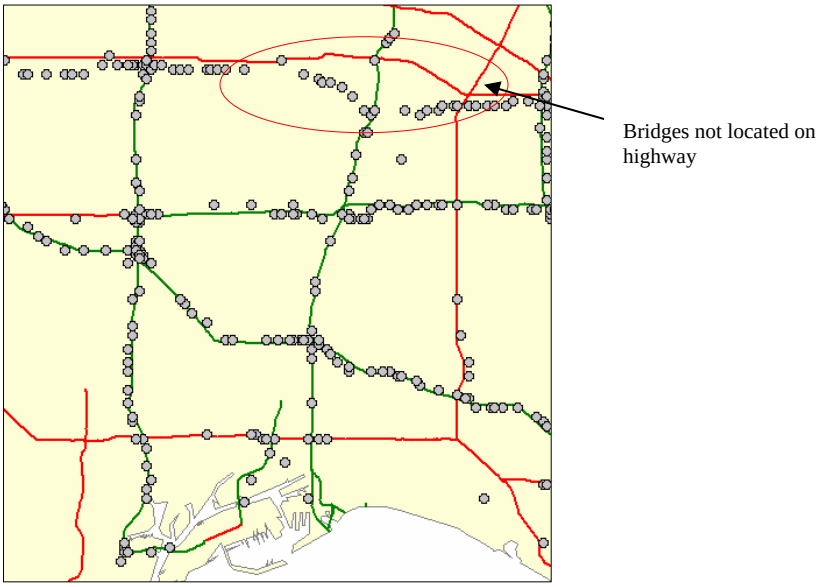


Figure 6.1. Example Illustrating Poorly Located Bridge Data Overlaid on Highway Data

Thematic maps aid in visualizing the data and should always be produced and reviewed when key fields are updated, such as class, replacement cost and square footage.

6.3 Using Database and Graphing Programs to Summarize Data

Summarizing HAZUS®MH tables with database or graphing programs is a useful method of checking the input data. This section presents several specific examples of how to use these tools to review the distribution and completeness of key data fields.

When sorting updated numeric data, bad values will often rise to the top or bottom of the list. The highest and the lowest values for quantitative fields should be reviewed and replaced if they are unreasonable. For example, the highest values in a replacement cost field are frequently erroneous. If the facility in question is indeed like any other, but the value is off by a factor of 100 or more, the value should be verified. Null, “0”, and typographical errors should be replaced with default values.

The SQL "Group-by" query accompanied with a “Count” is a powerful tool for checking data, which can be used to summarize any field that has been updated. For example, if the class field has been updated, the user should review how many facilities fall in each class. For utilities, there should be few very large facilities, and a greater number of medium and small sized facilities, although this will depend on the completeness of the data that was collected. Group-by queries allow the user to create histograms, which are an important statistical tool for understanding the distribution of data. For a given numeric field, the group-by query can be combined with average, minimum, maximum, and standard deviation statistics that present a useful summary. For example, if raw assessor data is collected, square footage values can be aggregated by census tract, and then generally compared with the default HAZUS®MH square footage. Group-by queries can be used to summarize more than one field, to assure values are correlated. For example, if replacement cost and square footage are summarized by census tract, compute the average cost per square foot and map these values. The results should be consistent, varying slightly by population density and income. Sum total residential square footage and population in each census tract to verify the number of people and square footage of residential buildings are correlated. Cross-tab queries in Access or pivot-tables in Excel allow two fields to be compared without summarizing by class or census tract. These may be employed when group-by queries require further scrutiny.

Figures 6.2 through 6.5 illustrate the process a user might go through to evaluate residential replacement cost for a hypothetical study region. In Figure 6.2, the user examines the updated replacement cost relative to each census tract’s population and discovers that there is good agreement, with the exception of one outlying value. The user then adds the default data to the graph, to see if the initial data reflects the anomaly (Figure 6.3). Since the value is still suspect, the user compares the updated replacement cost for each census tract with the default cost data for that census tract directly, using Excel to draw a trend line for the study region with (Figure 6.4) and without (Figure 6.5) the data. Since the updated data agrees with the default data with the exception of the anomalous value, the user reviews the household income of the census tract and the surrounding census tracts. Finding no significant difference, an aerial photo is reviewed. The user traces the anomaly to a single housing value of $99,999,999 in the original

database, and makes a decision to replace the value for this house with the average housing value for the tract without the anomaly. This example illustrates how data checking is a process of data visualization and examination, rather than following a specific set of procedural steps.

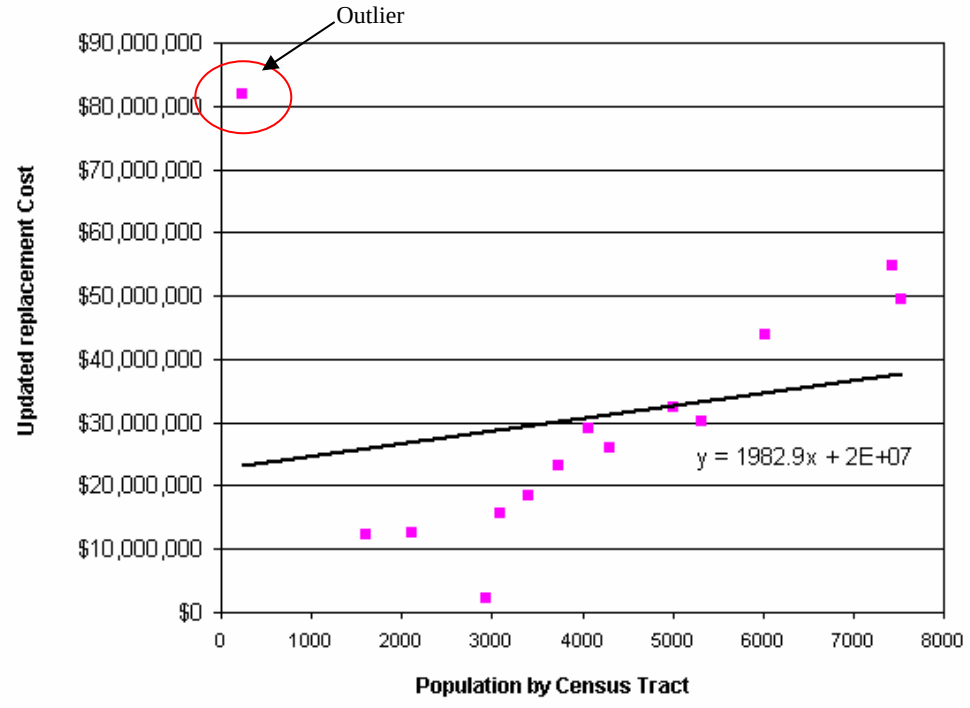


Figure 6.2. Updated Replacement Cost vs. Population by Census Tract

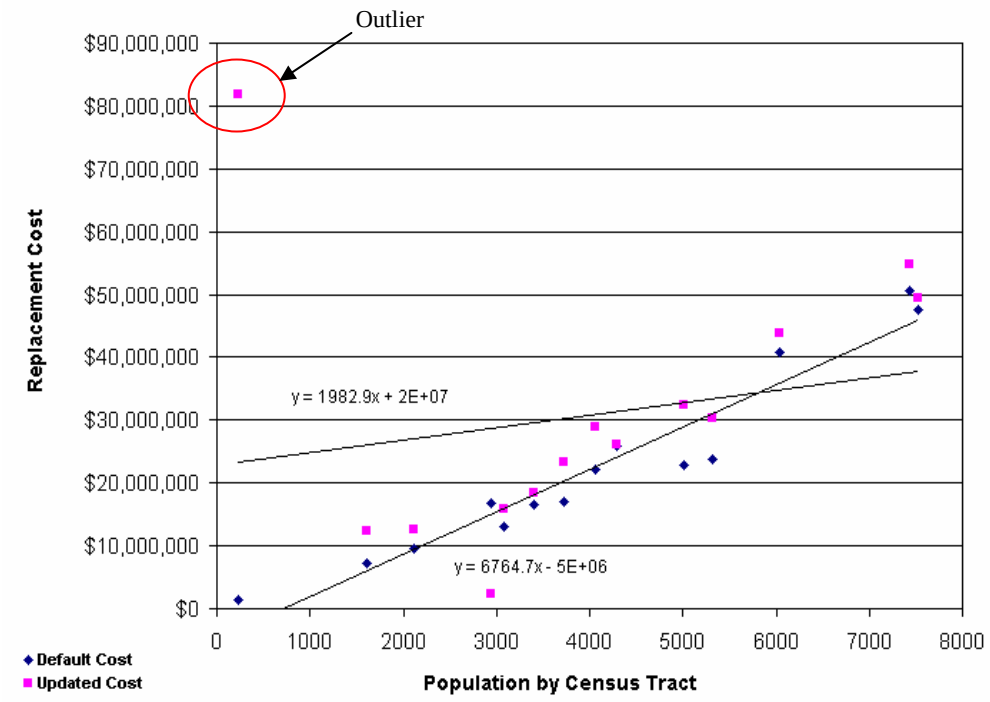


Figure 6.3. Default and Updated Replacement Cost vs. Population by Census Tract

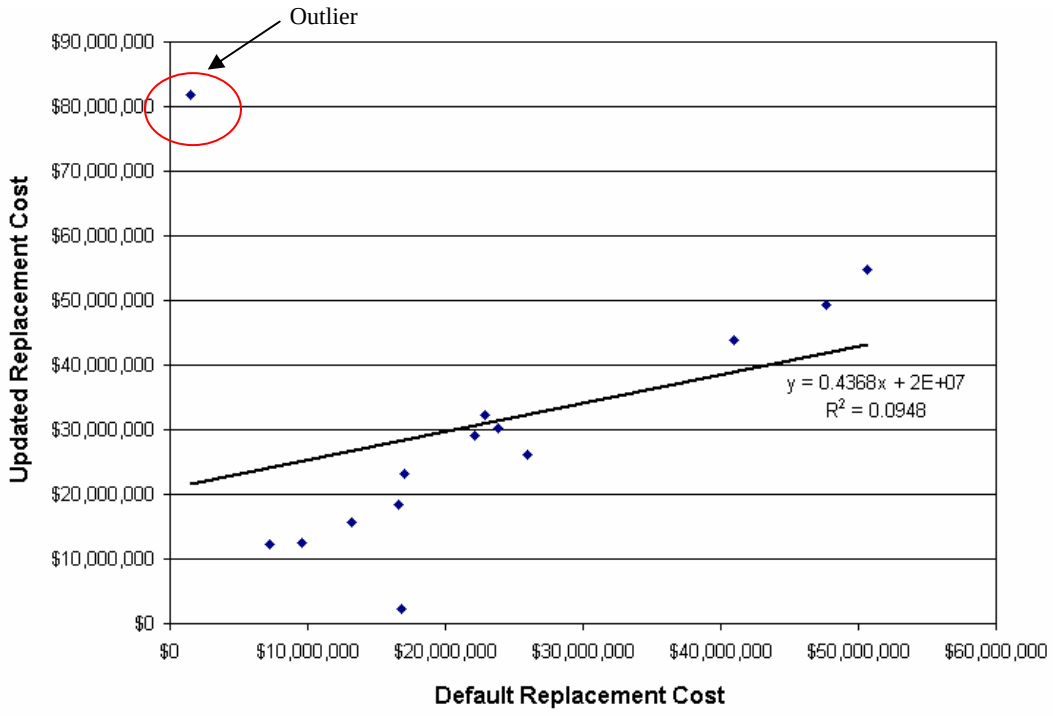


Figure 6.4. Updated vs. Default Replacement Cost, Trend Line Calculated with Anomalous Value

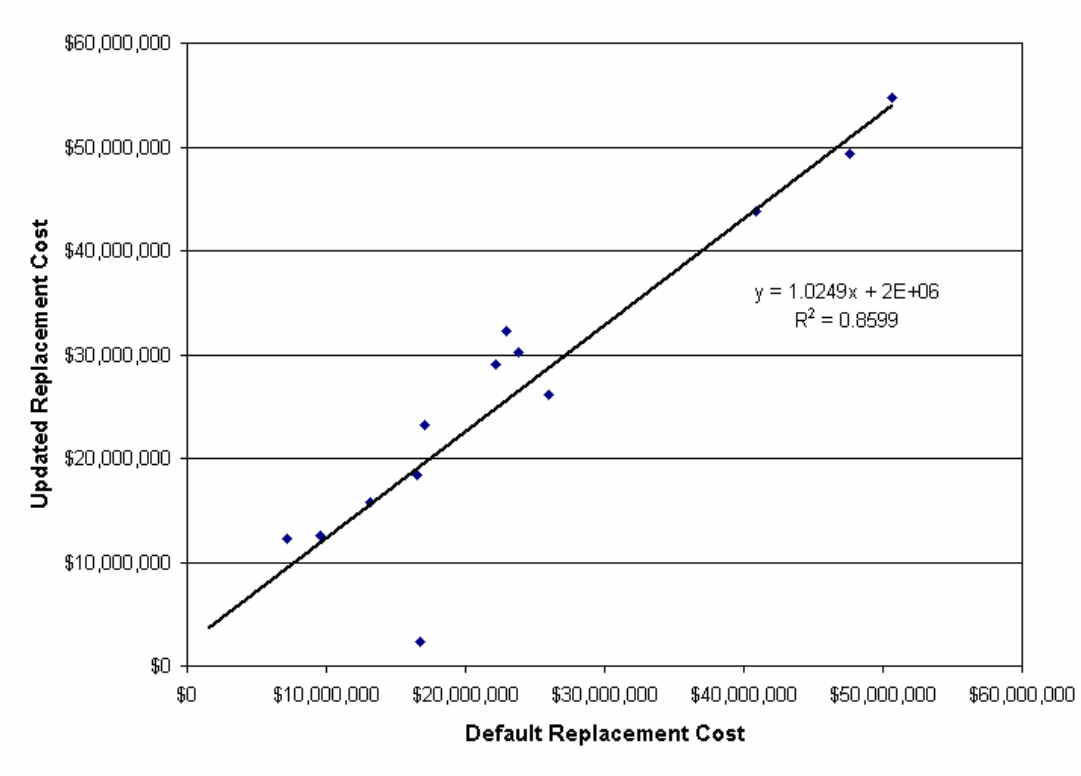


Figure 6.5. Updated vs. Default Replacement Cost, Trend Line Calculated without Anomalous Value

6.4 Checking Replacement Costs

When detailed inventory data are collected for use in HAZUS®MH, the default replacement cost assigned by HAZUS®MH may no longer be representative. Users may contact local agencies to discuss the HAZUS®MH class and replacement cost. Even if the basic inventory data is not being updated, a user may want to contact agency personnel to refine replacement costs for key analytic components. See Section 4.1 for a complete discussion of refining default lifeline facility replacement costs based on facility size or capacity. Updating the SQL Server tables can be done through Microsoft Access, but it is recommended that users make updates through the HAZUS®MH interface whenever possible.

The HAZUS®MH default general building stock replacement costs are engineering-based, national average replacement costs modified for local cost conditions, for a typical structure of each occupancy type. However, if the typical structure in the user's community is significantly different than the default building configuration for that occupancy, the default replacement cost may not be appropriate. For example, the default office (COM4) configuration is a mid-rise structure. If the local community has only low-rise office buildings (typical of more rural counties) and no mid-rise offices,

this default cost could be modified to better reflect local conditions. It would be useful, therefore, for the user to contact local building department personnel, local contractors, or real estate agents to discuss the reasonableness of the total replacement cost (sum of structural and non-structural repair costs in the complete damage state, multiplied by appropriate local cost modifier) for selected occupancies.

6.5 Reviewing Results for Possible Problems with the Input Data

Thematic mapping is an effective way of checking the accuracy of HAZUS®MH results. Create thematic maps of estimated losses and damage states and check for anomalies. For a particular study region, a cluster of census tracts with results that are significantly different than surrounding losses may indicate something is not correct. Check the underlying inventory or soil databases for unusual values. Although there might be an explanation, and the result may be correct, investigating such anomalies is worthwhile.

Outliers can be identified by visual inspection of ranges of attributes in thematic maps. There may be a data valuation or input problem if the results seem out of the ordinary. Figure 6-6 below provides a simplified example of verification of results with thematic mapping. The figure is a thematic representation of estimated losses by census tracts, where green indicates low dollar loss, yellow is medium dollar loss, and red is high dollar loss. For the particular study region, a single census tract with high loss in the center of an area with low losses should be an indication of abnormality of the loss estimates. It is important to note that there might be a logical explanation to this pattern, or it might be the result of a data processing or valuation problem.

The priority-rating scheme for lifelines discussed in Chapter 3 provides the user with an overview of the approximate contribution to loss of the various input tables in a HAZUS®MH analysis. Although individual results might vary with local conditions, if a medium or low loss contributor is amongst the high loss facilities, there may be a data valuation problem worthy of review.

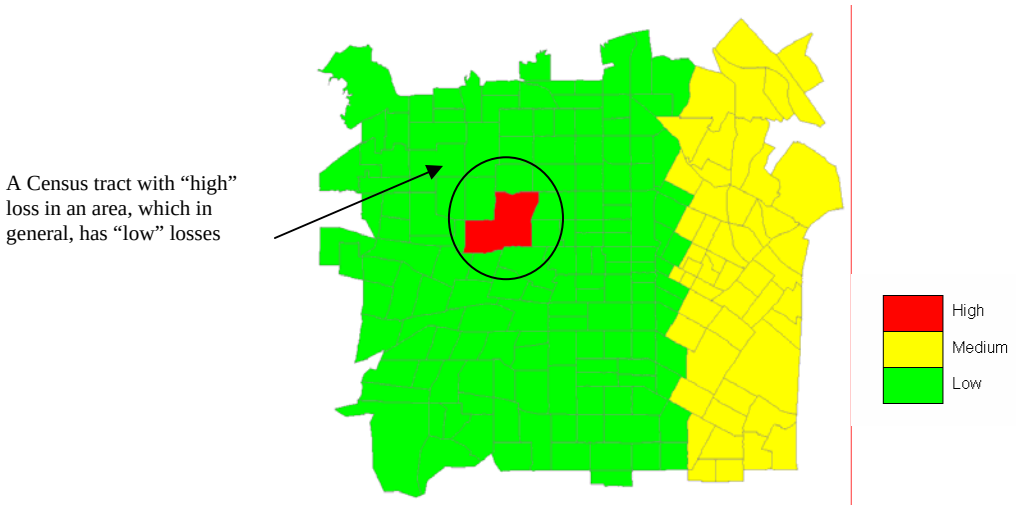


Figure 6.6. Verification of Results with Thematic Mapping

6.6 Reviewing HAZUS®MH Inventory Updated Using the BIRT Program

The BIRT program allows the user to make building inventory updates at two levels. BIRT Level 1 updates require no additional data and change the underlying exposure value and/or building count tables for a given study region. BIRT Level 2 updates allow users to replace square footage and building count data within a HAZUS®MH MR-1 study region with data derived from assessor's data or other sources, resulting in updated square footage values, building counts, and related exposure value tables

It is recommended that a user check the inventory modified using the BIRT program for both Levels 1 and 2. Depending on the level of analysis, users will need to check the exposure value tables, square footage tables and building count tables that are updated within HAZUS®MH. An example of how to check the updated exposure table through the HAZUS®MH interface is provided below. If after checking the updates through the interface, the user finds that the percent change between default and updated inventory data is greater than 50%, the data should be checked thoroughly. It is recommended that the user check the input data for mistakes or anomalous values. The default data should also be checked to determine if the default data in a specific region is particularly unsuitable.

The following is an example of how to use the HAZUS®MH interface to check BIRT updates:

Step 1: Beginning with the default inventory, access the exposure value data tables through the "Inventory", "General Building Stock", "Dollar Exposure" menu selections in the HAZUS®MH interface (See Figure 6.7). These tabulate total replacement costs or dollar exposure, in thousands of dollars, associated with the general building stock by census tract (See Figure 6.8).

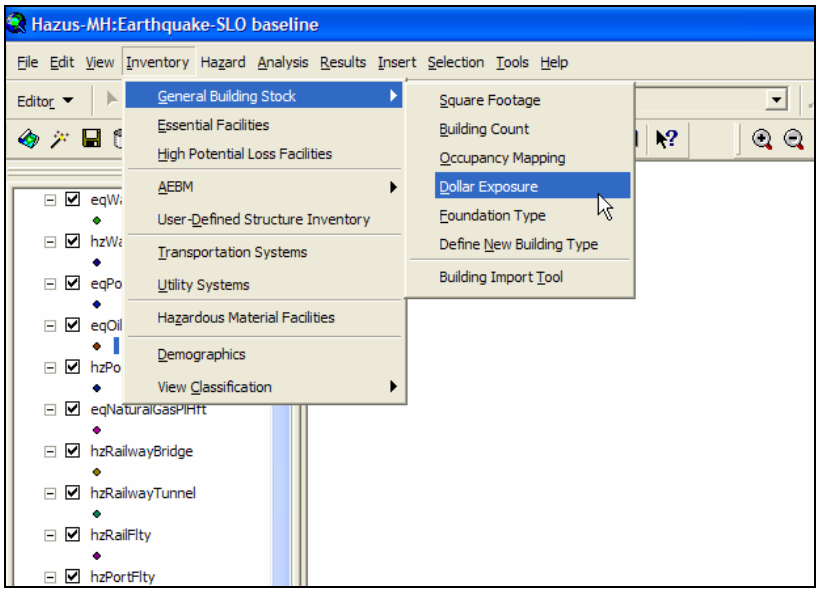
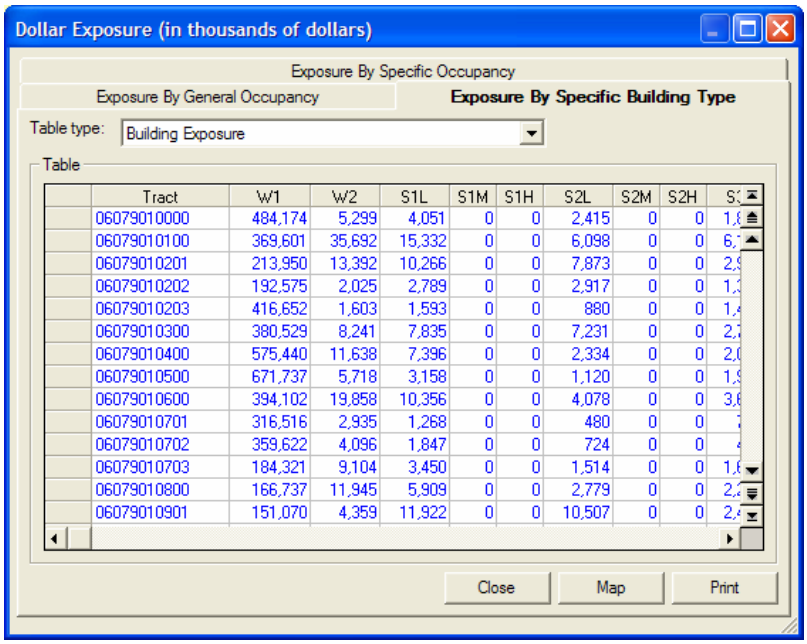


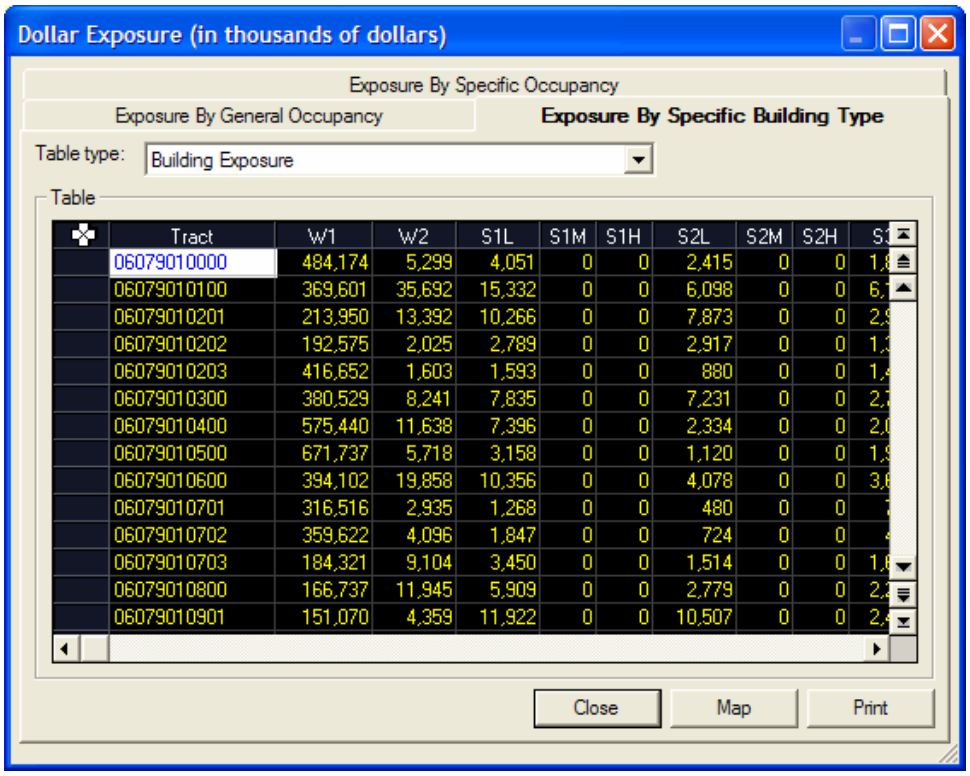
Figure 6.7. Accessing the Building Exposure by Specific Building Type Table



Tract	W1	W2	S1L	S1M	S1H	S2L	S2M	S2H
06079010000	484,174	5,299	4,051	0	0	2,415	0	0
06079010100	369,601	35,692	15,332	0	0	6,098	0	0
06079010201	213,950	13,392	10,266	0	0	7,873	0	0
06079010202	192,575	2,025	2,789	0	0	2,917	0	0
06079010203	416,652	1,603	1,593	0	0	880	0	0
06079010300	380,529	8,241	7,835	0	0	7,231	0	0
06079010400	575,440	11,638	7,396	0	0	2,334	0	0
06079010500	671,737	5,718	3,158	0	0	1,120	0	0
06079010600	394,102	19,858	10,356	0	0	4,078	0	0
06079010701	316,516	2,935	1,268	0	0	480	0	0
06079010702	359,622	4,096	1,847	0	0	724	0	0
06079010703	184,321	9,104	3,450	0	0	1,514	0	0
06079010800	166,737	11,945	5,909	0	0	2,779	0	0
06079010901	151,070	4,359	11,922	0	0	10,507	0	0

Figure 6.8. HAZUS®MH Dialog Presenting the Building Exposure by Specific Building Type

Step 2: Copy the values in the building exposure by specific building type table by clicking on the top-left gray cell in the table and pressing CTRL+C on the keyboard. The values to be copied will be highlighted in black (see Figure 6.9). Paste these values in a new Microsoft Excel worksheet (Figure 6.10). Repeat step 1 and 2 in the study region updated by BIRT. (Figure 6.11).



Tract	W1	W2	S1L	S1M	S1H	S2L	S2M	S2H
06079010000	484,174	5,299	4,051	0	0	2,415	0	0
06079010100	369,601	35,692	15,332	0	0	6,098	0	0
06079010201	213,950	13,392	10,266	0	0	7,873	0	0
06079010202	192,575	2,025	2,789	0	0	2,917	0	0
06079010203	416,652	1,603	1,593	0	0	880	0	0
06079010300	380,529	8,241	7,835	0	0	7,231	0	0
06079010400	575,440	11,638	7,396	0	0	2,334	0	0
06079010500	671,737	5,718	3,158	0	0	1,120	0	0
06079010600	394,102	19,858	10,356	0	0	4,078	0	0
06079010701	316,516	2,935	1,268	0	0	480	0	0
06079010702	359,622	4,096	1,847	0	0	724	0	0
06079010703	184,321	9,104	3,450	0	0	1,514	0	0
06079010800	166,737	11,945	5,909	0	0	2,779	0	0
06079010901	151,070	4,359	11,922	0	0	10,507	0	0

Figure 6.9. Copying the Building Exposure by Specific Building Type Table Values

	A	B	C	D	E
1		Tract	W1	W2	S1L
2		6079010000	484,174	5,299	4,051
3		6079010100	369,601	35,692	15,332
4		6079010201	213,950	13,392	10,266
5		6079010202	192,575	2,025	2,789
6		6079010203	416,652	1,603	1,593
7		6079010300	380,529	8,241	7,835
8		6079010400	575,440	11,638	7,396
9		6079010500	671,737	5,718	3,158
10		6079010600	394,102	19,858	10,356
11		6079010701	316,516	2,935	1,268
12		6079010702	359,622	4,096	1,847
13		6079010703	184,321	9,104	3,450
14		6079010800	166,737	11,945	5,909
15		6079010901	151,070	4,359	11,922

Figure 6.10. HAZUS®MH Default Building Exposure by Specific Building Type Table

	A	B	C	D	E
1		Tract	W1	W2	S1L
2		6079010000	470,101	5,766	4,400
3		6079010100	377,225	38,699	16,744
4		6079010201	217,306	14,679	11,223
5		6079010202	192,697	2,190	3,009
6		6079010203	419,573	1,743	1,756
7		6079010300	379,883	8,930	8,473
8		6079010400	576,313	12,699	8,177
9		6079010500	674,033	6,192	3,469
10		6079010600	399,998	21,626	11,397
11		6079010701	303,328	3,213	1,390
12		6079010702	349,312	4,521	2,020
13		6079010703	186,141	9,947	3,771
14		6079010800	159,286	13,295	6,498
15		6079010901	167,715	4,876	13,316

Figure 6.11. Updates to Building Exposure by Specific Building Type Table

Step 3: Using the following Microsoft Excel equation, compute the percent change in exposure for each census tract. For example, for W1 construction in the first census tract (cell C2), **[=(((SAMPLE_DEF!C2-SAMPLE_UPD!C2)) / ((SAMPLE_DEF!C2+ SAMPLE_UPD!C2)/2))]** where "SAMPLE_DEF" is the name of the spreadsheet with the default data, and "SAMPLE_UPD" is the name of the spreadsheet with updated data. The results are shown in Figure 6.12.

	A	B	C	D	E
1		Tract	W1	W2	S1L
2		6079010000	-2.9%	8.4%	8.3%
3		6079010100	2.0%	8.1%	8.8%
4		6079010201	1.6%	9.2%	8.9%
5		6079010202	0.1%	7.8%	7.6%
6		6079010203	0.7%	8.4%	9.7%
7		6079010300	-0.2%	8.0%	7.8%
8		6079010400	0.2%	8.7%	10.0%
9		6079010500	0.3%	8.0%	9.4%
10		6079010600	1.5%	8.5%	9.6%
11		6079010701	-4.3%	9.0%	9.2%
12		6079010702	-2.9%	9.9%	8.9%
13		6079010703	1.0%	8.8%	8.9%
14		6079010800	-4.6%	10.7%	9.5%
15		6079010901	10.4%	11.2%	11.0%

Figure 6.12. Percent Change in Building Exposure for Each Census Tract

Steps 1 to 3 above illustrate the process of checking exposure data. It is recommended that the user repeat these steps for building count after a BIRT level 1 analysis. For a BIRT level 2 analysis, building count, square footage and exposure should be checked. Once the user calculates the percent change, the results can be reviewed by census tract and overall. The change reflected in any given cell is due to a combination of factors, and may represent new development, changes in valuation, or more accurate information. All of these parameters need to be considered when checking the data for potential errors. In addition to examining the changes for specific census tracts, the user should review the aggregate changes in inventory to assess the overall impact of the updates.

References

Bouabid, Jawhar, Ivan Wong, Gilles Bureau, William Graf, Charles Huyck, Allan Porush, Timothy Siegel, Walter Silva, Michael Swigart, Ronald Eguchi, Jeff Rouleau, John Knight, and Tammie Dreher (2002), "A Comprehensive Seismic Vulnerability And Loss Evaluation Of The State Of South Carolina Using HAZUS: Part I Overview And Results", Proceedings of the Seventh U.S. National Conference on Earthquake Engineering, Boston, Mass., July, 2002, Paper 00061.

DHS/FEMA (2005). "Multi-hazard Loss Estimation Methodology: Earthquake Model, HAZUS®MH MR-1 Technical Manual", prepared by the National Institute of Building Sciences (NIBS) for the Department of Homeland Security, Emergency Preparedness and Response Directorate, Federal Emergency Management Agency, Mitigation Division.

EQE International (1996), *"Second Pilot Test Study of the Standardized Nationally Applicable Loss Estimation Methodology, Boston, Massachusetts, Task 4.2.3 Final Report"*, technical report prepared for the National Institute of Building Sciences, Washington, D.C.

EQE International (2000), *"Assessment of the Benefits of Implementing the New Seismic Design Criteria and Inspection Procedures"*, performed by EQE International for the SAC Steel Project.

Means (2002), *Means Square Foot Costs*, R.S. Means Company, Inc., Kingston, Massachusetts.

Means (2005), *Means Square Foot Costs*, R.S. Means Company, Inc., Kingston, Massachusetts.

NIBS (2002), *Earthquake Loss Estimation Methodology, HAZUS-99 Service Release 2 (SR2) Technical Manual*, prepared by the National Institute of Building Sciences for the Federal Emergency Management Agency, Washington, D.C.

Wills, C.J., Petersen, M., Bryant, W.A., Reichle, M., Saucedo, G.J., Tan, S., Taylor, G., and Treiman, J. (2000), "A Site-Condition Map For California Based on Geology and Shear-Wave Velocity" Bulletin of the Seismological Society of America, v. 90, s187-s208.

Annotated Bibliography

1. ATC (final publication pending), San Francisco's Earthquake Risk: Report on Potential Earthquake Impacts in San Francisco: Phase II, Task 2 Impact Assessment Report, prepared by the Applied Technology Council (ATC), Redwood City, California, for the San Francisco Department of Building Inspection, Community Action Plan for Seismic Safety (CAPSS), City and County of San Francisco.

   As part of San Francisco's "Community Action Plan for Seismic Safety" Phase 2 effort (administered by ATC), ABS Consulting performed a city-wide earthquake vulnerability assessment for various earthquake scenarios using HAZUS®99-SR2 This "Level 3" HAZUS® assessment included development of detailed building inventory data (built from individual building databases at the city block level, rather than at the HAZUS® default census tract level) and creation of customized mapping schemes associating construction types with building occupancies.

2. CUSEC (2003), Comparison Study of the 1985 CUSEC Six Studies Study Using HAZUS, prepared by the Central United States Earthquake Consortium, and available on-line at: http://www.cusec.org/Hazus/six_cities.htm

   This project used HAZUS®99 (at Level 1) to evaluate earthquake losses for six cities, including Little Rock, AR, Carbondale, IL, Evansville, IN, Paducah, KY, Poplar Bluff, MO, and Memphis, TN. This study represents an update to previous loss estimation efforts, reflecting better knowledge of the regional seismic hazard and changes in the built environment.

3. EERI (1997), Earthquake Spectra: Theme Issue of Earthquake Loss Estimation, Volume 13, Issue 4, pp. 565-855, Roger D. Borcherdt and Thalia Anagnos, editors.

   This issue of Earthquake Spectra (available on-line to members of EERI or for a fee at http://scitation.aip.org/dbt/dbt.jsp?KEY=EASPEF&Volume=13&Issue=4) contained a number of papers describing the original HAZUS® methodology, as listed below:

   - **"Development of a National Earthquake Loss Estimation Methodology",** Robert V. Whitman, Thalia Anagnos, Charles A. Kircher, Henry J. Lagorio, R. Scott Lawson, and Philip Schneider, pp. 643-661.

   - "**Development of Building Damage Functions for Earthquake Loss Estimation**", Charles A. Kircher, Aladdin A. Nassar, Onder Kustu, and William T. Holmes, pp. 663-682.

   - **"Direct and Indirect Economic Losses from Earthquake Damage",** David S. Brookshire, Stephanie E. Chang, Hal Cochrane, Robert A. Olson, Adam Rose, and Jerry Steenson, pp.683-701.

- "**Estimation of Earthquake Losses to Buildings",** Charles A. Kircher, Robert K. Reitherman, Robert V. Whitman, and Christopher Arnold, pp. 703-720.

4. EQE International (1996), Second Pilot Test Study of the Standardized Nationally Applicable Loss Estimation Methodology, Boston, Massachusetts, Task 4.2.3 Final Report, technical report prepared for the National Institute of Building Sciences, Washington, D.C.

   EQE International (now part of ABS Consulting) performed the second pilot test of the NIBS/FEMA HAZUS® earthquake loss estimation methodology (HAZUS®97). The test study was conducted for the Boston, Massachusetts. The purpose of the study was to test the methodology, evaluate the results produced and recommend improvements. A substantial part of the study was to collect seismic hazard data and develop the required ground failure susceptibility maps. The development of general building and lifeline inventories was also necessary in order to test the methodology's capability to produce better results when the software program's default data is substituted with better quality data.

5. EQE International (2000), Assessment ***of the Benefits of Implementing the New Seismic Design Criteria and Inspection Procedures***, performed for the SAC Steel Project.

   As part of the FEMA/SAC Phase II Steel Project, EQE International (now part of ABS Consulting) performed an assessment of benefits (i.e., reduced losses) resulting from implementation of the SAC steel moment frame Seismic Design Criteria and Inspection Procedures. Benefits associated with two scenario earthquakes (the 1994 Northridge earthquake and a M6.7 earthquake on the Elysian Park thrust fault) were estimated for the City of Los Angeles, using HAZUS®99-SR1. Default data were replaced with customized building inventories, updated cost data, and refined steel moment-resisting frame (SMRF) fragility curves (developed by Kircher & Associates), resulting in a Level 2 HAZUS® Analysis.

6. FEMA (2000), HAZUS®99 Estimated Annualized Earthquake Losses for the United States, Federal Emergency Management Agency (FEMA) Publication 366, Washington, D.C. Available on-line at http://www.fema.gov/hazus/li_pubs.shtm

   This study, conducted by Durham Technologies, Inc. for FEMA, estimates annualized direct economic earthquake losses for all counties and states in the United States using HAZUS®99 Service Release 1 (SR-1). The analysis indicated that the expected national annual loss to the national building stock amounts to $4.4 billion per year, with a significant amount concentrated in California (74%).

7. King & Pierce Counties (2001), Port-to-Port Transportation Corridor Earthquake Vulnerability, conducted as part of a Project Impact Partnership between King & Pierce Counties "Creating Disaster Resistant Communities", text available on-line from: http://www.fema.gov/hazus/dl_trans.shtm.

In this study, HAZUS®99 was used to assess the vulnerability of over 200 highway bridges along the I-5 transportation corridor between the ports of Seattle and Tacoma for King and Pierce Counties. Earthquake risk was evaluated by quantifying the hazards associated with six earthquake scenarios, evaluating bridge damage and associated route reliability and recovery time, and estimating regional economic impacts of corridor disruption.

8. Rowshandel, B., M. Reichle, C. Wills, T. Cao, M. Petersen, D. Branum, and J. Davis, Estimation of Future Earthquake Losses in California, California Geological Survey, available on-line at: http://www.consrv.ca.gov/CGS/rghm/loss/.

   This study, conducted by the California Geological Survey using HAZUS®99-SR2, estimated both scenario-based and annualized losses for all counties within California. While default building inventory data was utilized, customized probabilistic seismic hazard data and scenario ShakeMaps were used. Results presented include detailed maps of ground shaking and losses by county.

9. Tantala, Michael W., Guy J.P. Nordenson, and George Deodatis (2001) Earthquake Loss Estimation Study for the New York City Area, Second Year Technical Report, Princeton University, Department of Civil and Environmental Engineering, submitted to MCEER and funded by FEMA. Available on-line at: http://nycem.org/techdocs/lossEstYr2/default.asp

   This study, coordinated by MCEER and funded by FEMA Region II and the New York State Emergency Management Office (NYSEMO), uses HAZUS® (HAZUS®99 SR-1) to estimate potential earthquake losses for the New York City Area. The project included refinements to the HAZUS® default databases, including development of a detailed site-specific building inventory for Manhattan as well as determination of soil conditions. Building data taken from the New York City Department of Finance (assessor's data) was geocoded and used to develop the updated census-tract based building inventory, while the limited construction information was supplemented by field surveys.

10. ***A Comprehensive Seismic Vulnerability and Loss Evaluation of the State of South Carolina Using HAZUS*** (2002) Prepared for the South Carolina Emergency Preparedness Division, by URS Corporation, Durham Technologies, Inc., ImageCat, Inc., Pacific Engineering & Analysis, and S&ME, Inc.

    This study, funded through the South Carolina Emergency Preparedness Division (SCEPD), was a comprehensive seismic risk and vulnerability analysis for the State of South Carolina. In this evaluation, the project team estimated the potential losses from four scenario earthquakes using HAZUS®99, FEMA's geographical information system (GIS) software. Improved data on essential facilities, such as school buildings, hospitals and other critical facilities, as well as lifeline data for highways, railways, airports, water facilities, pipelines, and electric power facilities was collected and utilized in HAZUS®99-SR2 to predict the potential impacts of the four

scenario earthquakes. The results of this study included estimates of building and lifeline damages, casualties, induced and economic losses, and serves as valuable input for the development of an analytically-supported disaster response plan. The results of this study were documented in a series of technical papers presented at the Seventh U.S. National Conference on Earthquake Engineering, held in 2002:

- **A Comprehensive Seismic Vulnerability And Loss Evaluation Of The State Of South Carolina Using HAZUS: Part I Overview And Results**, Jawhar Bouabid, Ivan Wong, Gilles Bureau, William Graf, Charles Huyck, Allan Porush, Timothy Siegel, Walter Silva, Michael Swigart, Ronald Eguchi, Jeff Rouleau, John Knight, and Tammie Dreher, Seventh U.S. National Conference on Earthquake Engineering, Boston, Mass., July, 2002, Paper 00061.

- **A Comprehensive Seismic Vulnerability And Loss Evaluation Of the State Of South Carolina Using HAZUS: Part II Ground Motion Hazard**, Walter Silva, Ivan Wong, Timothy Siegel, Nick Gregor, Douglas Wright, Robyn Schapiro, Richard Lee, and Pradeep Talwani, Seventh U.S. National Conference on Earthquake Engineering, Boston, Mass., July, 2002, Paper 00058.

- **A Comprehensive Seismic Vulnerability and Loss Evaluation of the State of South Carolina Using HAZUS: Part III Liquefaction Hazard**, Timothy C Siegel, William M. Camp, III; Walter Silva, Ivan G. Wong, and Douglas Wright, Seventh U.S. National Conference on Earthquake Engineering, Boston, Mass., July, 2002, Paper 00059.

- **A Comprehensive Seismic Vulnerability and Loss Evaluation of the State of South Carolina Using HAZUS: Part IV Seismic Vulnerability of Building Structures**, William Graf, Allan Porush, and Jawhar Bouabid, Seventh U.S. National Conference on Earthquake Engineering, Boston, Mass., July, 2002, Paper 00062.

- **A Comprehensive Seismic Vulnerability and Loss Evaluation of the State of South Carolina Using HAZUS: Part V Lifelines, Essential Facilities, and Hazardous Materials Sites**, Charles Huyck, Lenica Castner, Jawhar Bouabid, and Ronald Eguchi, Seventh U.S. National Conference on Earthquake Engineering, Boston, Mass., July, 2002, Paper 00060.

- **A Comprehensive Seismic Vulnerability and Loss Assessment of the State of South Carolina Using HAZUS - Part VI: Dam Inventory and Vulnerability Assessment Methodology**, Gilles Bureau and George Ballentine, Seventh U.S. National Conference on Earthquake Engineering, Boston, Mass., July, 2002, Paper 00057.

Glossary

ACCESS	A database program developed by Microsoft. Access files have the extension MDB. An Access database may consist of tables, queries, forms, reports, macros and modules.
ArcGIS	A suite of Geographic Information System (GIS) software from ESRI (Environmental Systems Research Institute). At the core of ArcGIS, is the geodatabase technology which sets the logic for accessing and managing geographic datasets. HAZUS®MH MR-1 requires ArcGIS version 9.0 SP1 to run.
AEBM	Advanced Engineering Building Module. The AEBM procedures are an extension of the more general methods of the FEMA earthquake loss estimation methodology HAZUS®MH. The primary purpose of the AEBM is to support mitigation efforts by providing building-specific loss estimation tools for use by experienced seismic/structural engineers.
ALOHA	Area Locations of Hazardous Atmospheres (ALOHA). 3rd party module integrated into HAZUS®MH. A computer program developed by Environment Protection Agency (EPA) that predicts how a hazardous gas cloud might disperse in the atmosphere after an accidental chemical release.
Anchored	Braced or secured non-structural components or equipment, intended to resist earthquake shaking.
Annualized losses	Estimated dollar value of earthquake losses to building stock in a single year in a specified geographic region.
Attenuation Function	A mathematical function that characterizes the earthquake ground motion attenuation process. Attenuation is the decrease in seismic-signal amplitude as waves propagate from the seismic source. Attenuation is caused by geometric spreading of seismic-wave energy and by the absorption and scattering of seismic energy in different earth materials.
Backup Power	Power provided by generators and Uninterruptible Power Supply (UPS) units, to prevent systems failing due to power failure.
BAAMA	Bay Area Automated Mapping Organization. BAAMA is an organization of GIS professionals in the San Francisco Bay Region that promotes partnerships and teamwork with users of GIS technology to improve our environment and community.
BAR-GC	San Francisco Bay Area GIS Council. BAR-GC was formed in April, 2002 to foster regional GIS coordination, identify and encourage data sharing opportunities and provide input to the

	California GIS Council (CGC). The jurisdiction of the BAR-GC is the nine-county San Francisco Bay Area that includes Alameda, Contra Costa, Marin, Santa Clara, San Francisco, San Mateo, Solano, Sonoma, and Napa Counties.
Bias	Synonym for Building Quality within HAZUS®99. (Parameter in the inventory data for the general building stock.) The subclasses are: Code, Inferior, and Superior.
BIT	Building Inventory Tool in HAZUS®MH. Allows the user to import and aggregate building data, such as Assessor's data, for analysis as the general building stock.
BIRT	Building Inventory Replacement Tool.
Building Frequency	The building frequency is a measure of the number of times the building shakes back and forth every second. It is the reciprocal of building period. If a building has a period of 2 seconds, its frequency is 0.5 Hz (cycles per second).
Building Height (ranges)	A structural parameter that reflects the variation of typical building periods and other design parameters like response of buildings. In HAZUS®MH buildings are classified using the following height ranges: Low-rise= 1-3 stories, mid-rise= 4-7 stories, high-rise= >8 stories
Building Inventory	Collection of general building stock data that includes residential, commercial, industrial, agricultural, religious, government, and educational buildings.
Building Inventory Classification System	Two-dimensional matrix relating building structure (model building) types grouped in terms of basic structural systems and occupancy classes.
Building Loss	Building loss refers to structural and non-structural damage caused by an earthquake or any other event, i.e., repair costs. The various damage states for a building caused by an earthquake translate into a dollar value, which constitutes the losses for that particular building.
Building Period	Measure of time that a building takes to shake back and forth one time, as a response to an external force, e.g., earthquake shaking. Tall buildings have longer periods on the order of 1 to 4 seconds. Short buildings move back and forth very rapidly and have periods in the order of 0.1 to 0.4 seconds.
Building Quality	Construction quality. Also referred as Bias in HAZUS®MH. The subclasses are: Code, Inferior, and Superior.
Building Types	Building Structure (Model Building) Types. Refer to Model Building Type classification table in Chapter 3 of the HAZUS®MH Technical Manual (DHS/FEMA).

Business Interruption	Any event, whether anticipated (i.e., public service strike) or unanticipated (i.e., blackout) which disrupts the normal course of business operations at a location.
CASIL	California Geographic Information Systems (GIS) web portal. CaSIL is a collection of spatial data which are available for download. The California Mapping Coordinating Committee (CMCC) is in the process of developing a series of GIS-related web pages to provide information on State government GIS activities, access to statewide GIS data, and links to the larger California GIS community. The Spatial Information Library is work in progress.
Casualties (by severity)	Injury or death to human population caused by an earthquake. HAZUS®MH casualty estimates are classified according to four severity levels. These are: Severity 1: Injuries requiring basic medical aid that could be administered by paraprofessionals. Examples are a sprain, a severe cut requiring stitches, a minor burn (first degree or second degree on a small part of the body), or a bump on the head without loss of consciousness. Severity 2: Injuries requiring a greater degree of medical care and use of medical technology such as x-rays or surgery, but not expected to progress to a life threatening status. Examples are third degree burns or second degree burns over large parts of the body, a bump on the head that causes loss of consciousness, fractured bone, dehydration or exposure. Severity 3: Injuries that pose an immediate life threatening condition if not treated adequately and expeditiously. Some examples are: uncontrolled bleeding, punctured organ, other internal injuries, spinal column injuries, or crush syndrome. Severity 4: Instantaneously killed or mortally injured
CATS	Consequence Assessment Tool Sets, developed by SAIC for FEMA. Estimates losses from technological (or man-made) hazards, hurricanes and earthquakes.
CGS	California Geological Survey (formerly known as the California Division of Mines and Geology)
CGIA	California Geographic Information Association. A non-profit, state-wide organization formed in 1994, it supports the use, acquisition, exchange, and management of high-quality geographic information in the State of California among all interested agencies, institutions, companies, and individuals.
Characteristic Event	Earthquake event characteristic of a particular fault or fault segment.
CISN	California Integrated Seismic Network.

Complete Damage See *Damage State.*

Compressor Station Component of Natural Gas system. These serve to maintain the flow of gas in cross-country pipelines. Compressor stations consist of either centrifugal or reciprocating compressors.

Contents Loss Refers to loss of building contents. Building contents are defined as furniture and equipment that is not integral with the structure, like computers and other supplies. Contents do not include inventory or nonstructural components such as lighting, ceilings, mechanical and electrical equipment and other fixtures.

Damage Function Mathematical relationship for estimating building damage due to ground shaking.

Damage Ratio Cost of damage or repair as a fraction of replacement cost. Also see replacement cost.

Damage State Damage to building, transportation or lifeline systems described in terms of the nature and extent of damage exhibited by its components. In HAZUS®MH, damage is defined in terms of five damage states, and each damage state is described in terms of expected physical damage:

- None: No damage.
- Slight: buildings and facilities in the Slight damage state are assumed to have damage equal to approximately 2% of replacement value. For example, the definition of slight damage state in light-framed wood structure is as follows: Small plaster or gypsum board cracks at corners of door and window openings and wall ceiling intersections; small cracks in masonry chimneys and masonry veneer.
- Moderate: buildings and facilities in the Moderate damage state are assumed to have damage equal to approximately 10% of replacement value. For example, the definition of moderate damage state in light-framed wood structure is as follows: Large plaster or gypsum-board cracks at corners of door and window openings; small diagonal cracks across shear wall panels exhibited by small cracks in stucco and gypsum wall panels; large cracks in brick chimneys; toppling of tall masonry chimneys.
- Extensive: buildings and facilities in the Extensive damage state are assumed to have damage equal to approximately 50% of replacement value. For example, the definition of extensive damage state in light-framed wood structure is as follows: Large diagonal cracks across shear wall panels or large cracks at plywood joints; permanent lateral movement of floors and roof; toppling of most brick chimneys; cracks in foundations; splitting

of wood sill plates and/or slippage of structure over foundations; partial collapse of room-over-garage or other soft-story configurations; small foundations cracks.

- Complete: buildings and facilities in the Complete damage state are generally considered to be a total loss (economic loss = 100% of replacement value). For example, the definition of the complete damage state in light-framed wood structure is as follows: Structure may have large permanent lateral displacement, may collapse, or be in imminent danger of collapse due to cripple wall failure or the failure of the lateral load resisting system; some structures may slip and fall off the foundations; large foundation cracks.

Data Gaps Incomplete information in a database or table.

Design Level In HAZUS®MH refers to seismic design level, that is, the level of seismic design considered in the building code at the time of construction. Four design levels are defined in the HAZUS®MH methodology: High-Code, Moderate-Code, Low-Code and Pre-Code.

Deterministic Hazard Assessment An assessment that specifies single-valued parameters such as maximum earthquake magnitude or peak ground acceleration, without consideration of likelihood of occurrence.

DHS Department of Homeland Security. One of the agencies that is a part of DHS is Federal Emergency Management Agency (FEMA). FEMA prepares the nation for hazards, manages Federal response and recovery efforts following any national incident, and administers the National Flood Insurance Program.

Direct Economic Loss In the HAZUS®MH methodology, direct economic loss refers to the costs of structural and non-structural repair, damage to building contents, loss of building inventory, relocation expenses, lost wages and lost income.

Displaced Persons People displaced from a property due to earthquake damage.

Distribution Circuits Components of electrical distribution system. 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.

Dollar Exposure Estimated dollar value of risk associated with partial or total loss of property, lives, systems, or functions exposed to hazards.

Drift The relative inter-story displacement of a building subject to lateral loads.

Essential Facilities	Facilities that provide services and are key to the functioning of a community are considered essential facilities. Examples of essential facilities include hospitals, police stations, fire stations, emergency operations centers (EOC), and schools.
Exceedance Probability	Exceedance probability (EP) refers to the cumulative probability of exceeding a given event or loss one or more times during a given duration of time. A 1% EP loss for a period of 50 years means that there is 1 in 100 chance of that particular loss being exceeded at least one time during that period of time.
Exposure	Lives, property, systems, or functions at risk of partial or total loss exposed to hazards.
Extensive Damage	See *Damage State*.
FEMA	Federal Emergency Management Agency
FFE	Fire following Earthquake. A model of induced loss estimation in HAZUS®MH.
Foundation Type	Structural type of support for building, transportation facilities, and lifeline facilities. Deep foundations include piles. Other example are spread footings. Foundation type is critical to performance when subject to permanent ground deformations. For example, buildings on deep foundations perform much better than buildings on spread footings, if the ground settles.
Frequency	In the context of risk analysis, frequency refers to how often an event or outcome will occur, given a specified exposure period. In the context of earthquake engineering and structural analysis, frequency is the inverse of a period of vibration.
Functionality	Refers to operational status of building or transportation system expressed a percentage of fully functional (100% functionality)
General Building Stock	Collection of all buildings in a region. The general building stock includes residential, commercial, industrial, agricultural, religious, government, and educational buildings.
General Occupancy	Classification of building use. Within HAZUS®MH, the General Occupancy classification system consists of seven groups: Residential, commercial, industrial, religion/nonprofit, government, education and agriculture.

Generation Plants	Electric power generation plants are components of an electric power system. Generation plant components include diesel generators, turbines, racks and panels, boilers and pressure vessels, and the building in which these are housed. The size of the generation plant is determined from the number of Megawatts of electric power that the plant can produce under normal operations. Within HAZUS®MH, small generation plants are those with a generation capacity of less than 200 Megawatts, while medium/large generation plants are those with a capacity greater than 200 Megawatts.
GUI	Graphical User Interface
Ground Failure	Refers to permanent ground displacement caused by an earthquake. Types of ground failures considered in HAZUS®MH include liquefaction, landsliding, and surface fault rupture. Ground failure is quantified in terms of permanent ground deformation (PGD), usually measured in inches.
Ground motion	Refers to vibrational movement of the ground due to earthquake. Ground motion is measured in terms of a variety of parameters. Parameters utilized by HAZUS®MH include spectral response (acceleration, velocity, and displacement), peak ground acceleration, and peak ground velocity. The spatial distribution of ground motion is of relevance in the HAZUS®MH methodology and it is estimated using various attenuation and other relationships.
Hazard	Refers to the frequency and severity of a threat inflicting losses on people, property, systems, or functions. Natural hazards are those hazards beyond the control of human beings, e.g., earthquakes, hurricanes, tornadoes, flood, brush fires, etc. Man-made hazards are those initiated by human intervention, or lack thereof, whether intentionally or unintentionally, direct or indirect, e.g., nuclear fallout, urban fires, asbestos, malpractice, auto accidents, etc.
Hazard Mitigation	The preventative actions undertaken in pre-disaster conditions to reduce the adverse effects of disaster due to hazards. Mitigation hinges on the notion that investing in preventative measures that reduce potential losses, far outweigh the cost of repair and reconstruction in the aftermath of disasters. Mitigation efforts can be structural or community outreach programs focusing on performance of structures under hazardous conditions, life safety, functionality and economy.
Hazardous Materials	Hazardous materials are those chemicals, reagents or substances that exhibit physical or health hazards, whether the materials are in a usable or waste state.

HAZUS®99	HAZUS®99 (Hazards U.S.) is a software package developed by Federal Emergency Management Agency (FEMA) under contract with the National Institute for Building Sciences (NIBS) to estimate losses due to earthquakes within the United States.
HAZUS®MH	HAZUS®MH - Multi Hazard. An updated and more recent version of HAZUS®99 with modules for loss estimation from Earthquake, Flood, and Wind (Hurricane).
HAZUS®MH MR-1	HAZUS®MH Maintenance Release 1. An updated and more recent version of HAZUS®MH released in January, 2005.
HAZUS®MH MR-2	HAZUS®MH Maintenance Release 2. An updated version of HAZUS®MH MR-1 slated to be released in Summer, 2006.
High Potential Loss Facilities	Facilities that are likely to suffer heavy earthquake losses if damaged. Within the HAZUS®MH methodology, high potential loss (HPL) facilities include nuclear power plants, dams, and some military installations.
Impact Assessment	Evaluating direct and indirect effects of a major event like an earthquake.
Indirect Economic Loss	In addition to the direct physical damage and economic losses, natural hazards like earthquakes cause a chain reaction, or ripple effect, that is transmitted throughout the regional economy. These could be business interruptions or disruption of retail activities. Such interruptions are indirect economic losses due to an event.
Induced Losses	Potential for losses due to an induced secondary event following or caused by a primary event. For example, Flood-induced damage in an earthquake can result from tsunamis (seismic sea waves), seiches (sloshing effects in lakes and bays) or dam or levee failure.
Inference Algorithms	Approaches for filling data gaps when available data fail to meet the minimum standard.
Inundation	Flooding due to natural or man-made causes.
Instrumental Intensity	A subjective numerical index captured by sensors, describing the severity of an earthquake in terms of its effects on the Earth's surface on humans and their structures.
Land Use	The purpose for which land or the structures on the land are being utilized; for example: commercial, residential, retail.
Lifelines	Refers to transportation and utility systems.
Liquefaction	Refers to a phenomenon resulting from ground shaking due to an earthquake, in which soil loses its strength and behaves as a liquid.

Mapping Scheme	A distribution of structural classes (model building types) by building use or occupancy, used within HAZUS to represent the general building stock.
MARPLOT	Mapping Applications for Response, Planning, and Local Operational Tasks. MARPLOT is a part of CAMEO®, a system of software application used to plan for and respond to chemical emergencies. Developed by EPA's Chemical Emergency Preparedness and Prevention Office (CEPPO) and the National Oceanic and Atmospheric Administration Office of Response and Restoration (NOAA).
MaSC	Mapping Scheme Converter tool.
Model Building Types	Building classes grouped together by basic structural system. Examples of model building types are light wood frame, mobile home, steel braced frame, concrete frame with unreinforced masonry infill walls, and unreinforced masonry.
Moderate Damage	See *Damage State*.
Modified Mercalli Scale (MMI)	A system for measuring the damage that occurs in an earthquake. The scale ranges from I to XII, where a MMI of I is not felt by people and a MMI of XII causes essentially total damage to the built environment.
MSDE	Microsoft SQL Server 2000 Desktop Engine. SQL Server is a platform for developing client applications needing an embedded database, local data storage, and lightweight Web applications.
Natural Period of Vibration	The time required to complete one cycle of motion in harmonic vibration. A single-degree-of-freedom oscillator, such as a simple pendulum, has a single natural period of vibration. A complex structure, such as a building, may vibrate in many different elastic modes, each having an associated period of vibration.
NEHRP	National Earthquake Hazards Reduction Program
NIBS	National Institute of Building Sciences
Non-structural Acceleration Sensitive	Damage category of non-structural component of buildings. Damage to acceleration-sensitive nonstructural components is primarily a function of floor acceleration.
Non-structural Drift Sensitive	Damage category of non-structural component of buildings. Damage to drift-sensitive nonstructural components is primarily a function of inter-story drift.
Occupancy	Usage categories associated with buildings. HAZUS®MH uses an occupancy classification system of 33 specific and 7 general occupancy classes. See also "general occupancy" and "specific occupancy"

OES	California Governor's Office of Emergency Services
Parcel Data	Parcel data reflect the legal boundaries and dimensions of smallest land subdivision units, and serve as the basis for land value assessments. The Assessor Department establishes and maintains maps for assessment purposes that delineate every parcel of land in most counties.
Peak Ground Acceleration	The highest acceleration measured by an accelerograph. . Measured as a percent of gravity, or "g".
Peak Horizontal Acceleration	An instrumental measure of earthquake ground motion intensity, normally taken from a tri-axial earthquake accelerogram as the maximum value recorded from either of the two horizontally-oriented axes.
Peak Vertical Acceleration	An instrumental measure of earthquake ground motion intensity, normally taken from a tri-axial earthquake accelerogram as the maximum value recorded from the vertically-oriented axes.
PESH	Potential earth science hazards. In the HAZUS®MH methodology PESH include ground motion (PGA, PGV, spectral acceleration, spectral velocity), ground failure (liquefaction, landslide and surface fault rupture), tsunami, and seiche.
PGD	Permanent Ground Deformation. This is a quantification of the ground failure that occurs because of liquefaction, landslides, and surface fault rupture. It is measured in inches and describes how far the surface of the ground moves.
Point Source	An earthquake source process where the aerial extent of slip on the fault rupture surface is considered to occur at an idealized point in the earth in estimating strong ground motions.
Probabilistic Hazard Assessment	An assessment that stipulates quantitative probabilities of the occurrences of specified hazards, usually within a specified time period.
Pumping Plant	Pumping plants are sub-components of potable water systems and oil systems. Usually comprised of a building, one or more pumps, electrical equipment, and in some cases, backup power systems.
Recurrence Interval	The recurrence interval (return period) is the average time span between large earthquakes on a particular fault.
REDARS	Risk from Damage to Roadway Systems (REDARS). Software developed for the Federal Highway Administration to assess losses to highways due to damage from earthquakes
Refineries	Component of Oil Systems. They are used for processing crude oil.

Replacement Cost	The cost to replace a building, facility, or a component at its current price with no deduction for depreciation.
Restoration Function	Mathematical function that estimates the fraction (or percentage) of a component expected to be operational as a function of time following an earthquake. For example, an extensively damaged roadway link might be closed (0% functional) immediately following the earthquake, but 100% functional after 30 days.
Return Period	Refers to how often an event or loss occurs. For example, a 100-year flood refers to the flood that occurs on average once every hundred years. See also recurrence interval.
Risk	The chance or probability that some undesirable outcome, such as injury, damage, or loss, will occur during a specified exposure period.
SANGIS	San Diego Geographic Information System. The City and County of San Diego created a partnership in GIS which was formalized into SanGIS. SanGIS focuses on ensuring geographic data is maintained and accessible for the San Diego Area.
Scenario	Particular set of attributes defining an earthquake event.
Seiche	Waves in a lake or reservoir that are induced because of ground shaking.
Seismicity	The geographic and historical distribution of earthquakes.
ShakeMap	Regional ground motion maps (instrumental intensity, peak ground velocity and peak ground acceleration) available from the USGS for Northern and Southern California, as well as the Pacific Northwest and Utah. ShakeMaps in California are available in real-time after an actual earthquake. In addition, the USGS has made a number of planning scenario ShakeMaps available on their website. It should be noted that downloadable versions of ShakeMap formatted for use in HAZUS®MH are available. See: http://earthquake.usgs.gov/shakemap/nc/shake/ and http://www.trinet.org/shake/
ShakeCast	An USGS application for automating ShakeMap delivery to critical users and for facilitating notification of shaking levels at user-selected facilities. http://earthquake.usgs.gov/resources/software/shakecast/
Situs	Place where something exists or originates
Slight Damage	See *Damage State*.
Soil Profile	Soil Profile refers to the layers of soil and site soil conditions.

Soil Type	Classification of site soil conditions within HAZUS®MH, as defined by NEHRP: a: hard rock (Eastern United States sites only) b: rock c: very dense soil and soft rock d: stiff soils e: soft soils f: soils requiring site specific evaluation
Specific Occupancy	Classification of building use. Within HAZUS®MH, the specific occupancy classification system consists of 33 classes: RES 1, RES 2, RES 3A-C, RES 4, RES 5 and RES 6 [8 classes], COM 1 - COM 10 [10 classes], IND 1- IND 6 [6 classes], REL 1 [1 class], GOV1- GOV 2 [2 classes], EDU1 - EDU 2 [2 classes], and AGR 1. [1 class]. Refer to Chapter 3 in the HAZUS®MH Technical Manual (DHS/FEMA).
Spectral Acceleration	Response of a suite of single-degree-of-freedom oscillators to an earthquake, used to represent forces on a structure. [The acceleration of earthquake motion at a specified building period. See definition of spectral velocity].
Spectral Velocity	The velocity of earthquake motion at a specified building period.
Substations	Electric substations are facilities that serve as a source of energy supply for the local distribution area in which they are located.
Tank Farms	Tank farms are subcomponents of the oil systems and store fuel products. These include tanks, pipes and electric components.
Tax Assessor Data	Data on land value and tax assessment maintained and updated regularly by county tax assessor. These databases often contain data useful in loss estimation, such as building size, age, use, and location.
Topology	Topology is a GIS term referring to the configuration of connections between nodes. Within HAZUS®MH, this concept applies to the characterization of lifeline systems, where the nodes could be source or terminal facilities, and the links could be pipelines.
TriNet	A five-year collaborative project conducted by the USGS, CGS, and the California Institute of Technology with funding from the Hazard Mitigation Grant Program from the Northridge Earthquake to create a better, more effective real-time earthquake information system for Southern California. TriNet is now part of the California Integrated Seismic Network (CISN).

Tsunami	Tsunami or “harbor waves” are ocean waves caused by the direct effects of subduction earthquakes and the secondary effects of earthquake triggered submarine landslides. These waves can reach heights greater than 10 meters.
USGS	United States Geological Survey
Vulnerability	A building or transportation system component or a lifeline component's susceptibility to damage or loss from a specific hazard.