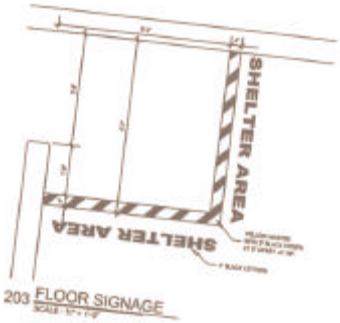
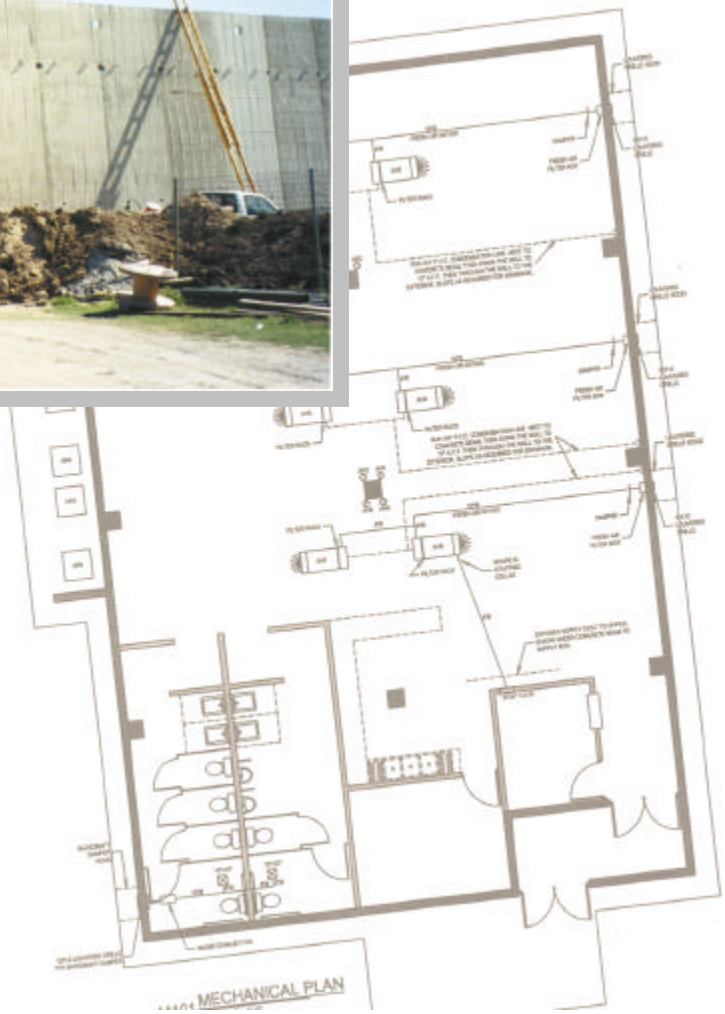
USER'S GUIDE

Benefit-Cost Analysis Software for Tornado and Hurricane Community Shelters



Version 1.00
July 2000



Federal Emergency Management Agency
Mitigation Directorate
500 C Street, SW
Washington, DC 20472
www.fema.gov

Table of Contents

Project Team

The Project Team that participated in the development of this software was composed of engineers from FEMA's Mitigation Directorate and Dewberry & Davis, LLC. Other engineers and university professors participated in pre-release review of the software.

FEMA

Clifford Oliver, CEM, CBCP
Chief — Building Sciences and Assessment Branch, Mitigation Directorate

Paul Tertell, P.E.
Project Officer and Senior Engineer — Building Sciences and Assessment Branch, Mitigation Directorate

Consultants

Daniel E. Medina, Ph.D., P.E.
Project Manager, Dewberry & Davis, LLC

Shane Parson, Ph.D.
Water Resources Engineer, Dewberry & Davis, LLC

Review Team

Daniel Deegan, P.E. (URS Greiner Woodward-Clyde), Robert Franke (FEMA), Terri McAllister, Ph.D., P.E. (Greenhorne & O'Mara, Inc.), Steven Pardue (FEMA), Scott Schiff, Ph.D. (Clemson University), Corey Schultz (PBA Architects), Scott Tezak, P.E. (Grenhorne & O'Mara, Inc.), Jason Trent (Storm Prediction Center, NOAA).

Daniel Medina wishes to express his gratitude to Dr. Martin Kulldorff, Biostatistician at the University of Connecticut, for sharing his ideas during informal exchanges that became invaluable contribution to the formulation of the tornado statistical analysis.

Disclaimer

The results produced by use of this Benefit-Cost Analysis Program are neither conclusive evidence that a proposed project is cost-effective, nor a guarantee that a project is eligible for any government grant for whatever purpose.

The software program accompanying this manual was developed under contract with the Federal Emergency Management Agency (FEMA).

FEMA and the software developers have checked this version carefully and have verified the results by comparison to earlier versions to assure that the program is fully operable. However, users of this manual and/or the accompanying software assume responsibility for the results of calculations.

Please document and report any problems discovered with this version of the Benefit-Cost User's guide or software to FEMA by email at paul.tertell@fema.gov.

1 Introduction

1.1 Scope of the Manual and Software

This manual and accompanying software were prepared for the use of the Federal Emergency Management Agency (FEMA) in conducting benefit-cost analyses of hazard mitigation projects for tornado and hurricane shelters.

1.2 Hazard Mitigation and Benefit Cost Analysis

Hazard mitigation projects are specifically aimed at reducing or eliminating future damages. Although hazard mitigation projects may sometimes be implemented in conjunction with the repair of damages from a disaster, the focus of hazard mitigation projects is on strengthening or improving buildings to enhance their ability to withstand the impacts of future disasters.

Benefit-cost analysis compares the "benefits" and "costs" of a proposed hazard mitigation project. For tornado and hurricane shelters, the only benefits considered are avoided future deaths and injuries in the shelter that are expected to occur as a result of the mitigation project. In other words, benefits are the reduction in expected future deaths and injuries (i.e., the difference in expected future deaths and injuries before and after the mitigation project). These benefits are monetized using Federal guidelines for loss of life and injury. The costs considered are those necessary to implement and maintain the specific mitigation project under evaluation.

Costs are generally well determined for specific projects for which engineering design studies have been completed. Benefits, however, must be estimated probabilistically because they depend on the improved performance of the building or facility to future tornado and hurricane events, the timing and severity of which are random variables.

The "benefits" calculated by the program are expected annual benefits, which are estimated over the useful lifetime of the mitigation project. To account for the time value of money, a net present value calculation must be performed. This calculation is done automatically in the program, using the discount rate and project useful lifetime entered by the user. Results of benefit-cost calculations are presented two ways: first, the benefit-cost ratio (benefits divided by costs) and second, the net benefits (benefits minus costs).

To estimate future damages (and the benefits of avoiding them), the probabilities of tornado and hurricane future events must be considered. The probabilities of future events profoundly affect whether or not a proposed hazard mitigation project is cost effective.

Mitigation may not be cost-effective even though a particular facility experienced great damage in a past event due to an event with a low probability of occurrence (i.e., a 500- or 1000-year event). Conversely, mitigation may be cost effective even though the particular facility experienced little or no damage in a past event, due to a higher probability of occurrence.

Each proposed hazard mitigation project must be evaluated on its own merits to compare the benefits and costs of a specific project. There are no "rules of thumb" to identify cost-effective projects because the costs and benefits of each project are different. The benefits of a particular project may vary markedly depending on the occupancy of a facility, the probabilities of future wind events, and the effectiveness of the mitigation measure in avoiding future damages.

The Benefit-Cost analysis software for tornado and hurricane shelters only accounts for avoided deaths and injuries to shelter occupants. The software does not consider benefits from reduced building or contents damage or reduced cost for evacuation and relocation. The software was developed on the assumption that the shelter's pre-mitigation (current) occupancy levels for tornadoes and hurricanes events will be the same as the post-mitigation occupancy levels. The presence of mitigation measures for an existing shelter will not increase the number of occupants in a shelter, but will increase the protection to the existing occupants.

1.3 Overview of Manual

This User's Guide details the use and implementation of the Benefit-Cost Analysis software for Tornado and Hurricane Shelters.

Chapter 2 *Getting Started* describes the hardware and software requirements and model installation.

Chapter 3 *Program Basics* details the basic use, navigation, and commands for the model.

Chapter 4 *Tutorial* builds step-by-step a mitigation project file using the model and will show how reports can be generated from completed project files.

Chapter 5 *Using the Program* provides information about data sources and calculation methods and assumptions.

2 Getting Started

2.1 Hardware and Software Requirements

The Benefit-Cost Analysis Model for Tornado and Hurricane Shelters is a stand-alone software application. The application requires

- IBM-compatible computer (PC) with Pentium 90MHz or faster microprocessor.
- VGA 1024 × 768 or higher resolution screen supported by Microsoft Windows.
- 24MB RAM for Windows 95 or later, 32MB for Windows NT.
- Hard drive with at least 50 MB of free disk space.
- CD-ROM drive.
- Microsoft Windows 95 or later or Microsoft Windows NT 3.51 or later
- Adobe Acrobat Reader 3.0 or later. The CD contains software to install Acrobat Reader on several platforms. Alternatively, the software can be downloaded from www.adobe.com.

2.2 Software Installation

It is recommended to close all other applications before installing the software. For NT users, be sure you have software installation privileges for your computer or have your system administrator install the software.

1. From Windows, run *Setup.exe* from the CD-ROM. One way to do this is to use Window Explorer to navigate to the CD-ROM drive and double-clicking on the *Setup.exe* file. Also, the Run command under the Start button can be used to type *d:/Setup.exe*, where *d:* should be substituted by the actual letter for the CD-ROM drive.

2. The setup program will initially copy some of the necessary files and check your system configuration. Depending on the configuration, the installation program may ask you if you want to update these files. In this case you will need to restart your computer and run *Setup.exe* again after the machine reboots. After this step has been completed, you will be prompted to start the software installation by clicking on the *OK* button. You can also cancel the installation program by clicking on the Exit button.

3. If you clicked *OK*, the next screen will contain the options to Exit, to change the installation directory, and to install the software to the specified directory.

   By clicking the Change Directory button, you will have the option to change the directory where the software will be installed. The selected hard drive should

have at least 50 Mb of free space. If you type the name of a folder that does not exist, you will be asked if you want this folder to be created.

After the installation directory has been set, click the button with the computer and disk graphic to start the software installation. The program will ask you to choose a name for the program group under which the model will reside. The installation software will then proceed to copy to your hard drive all of the required files. A status window will show the progress and the files being installed.

During the installation process, you may be prompted about whether to overwrite an existing file with a new file from the installation program. The typical situation is when the setup program detects a *dll* file with the same name as the one about to be installed. In many cases, the file being written by the installation program is a more recent version of the *dll* in the computer and could replace the existing file. If you are unsure, you may skip overwriting the file; however, there is a chance that the benefit-cost software may not operate properly.

The install program will copy files to the specified installation directory and the Windows system, will update the registry, and will add a new item under the Windows taskbar *Start* button, *Programs* menu: *Tornado and Hurricane Shelter Mitigation*. This item contains the following:

Benefit Cost Model	Starts the model
Benefit Cost Model Help	Opens the model's help file
User's Guide	Opens the *pdf* document containing this User's Guide.
Evaluation Checklists	Opens a *pdf* document containing the wind hazard evaluation checklist (described in FEMA Publication 361 *Design and Construction Guidance for Community Shelters*)

The User's Guide and Evaluation Checklists are copied to a folder labeled *Tornado & Hurricane BC Model*, under the destination selected for installation of the program. These files can also be found in the installation CD.

4. After all of the files have been copied and the registry updated, the installation program will display a window that indicates that the software installed correctly. Click the OK button and the installation program will close. Before running the model for the first time, be sure to restart your computer.

   After the software is installed a shortcut can be created on the desktop by clicking on the Windows *Start* button, *Tornado and Hurricane Mitigation* and right-clicking on *Benefit Cost Model* and dragging it to the desktop.

2.3 Uninstalling the Software

The install program automatically creates an uninstall procedure for the software. It will delete all files and directories created by the install program.

1. In the *Start* button, select the *Settings* and then *Control Panel*.

2. In the *Control Panel* window, double-click the *Add/Remove Programs* icon.

3. In the *Add/Remove Programs* window, under the *Install/Uninstall* tab, select from the list the *Tornado and Hurricane Benefit Cost Model* item and click the *Add/Remove* button.

4. The install procedure will remove all files and directories installed by the install program. It will also remove the *Programs* menu item for the software. You may be prompted about removing shared files. Usually you do not uninstall shared files, since other programs may require those files. You may also be notified if there was a problems deleting certain files or directories.

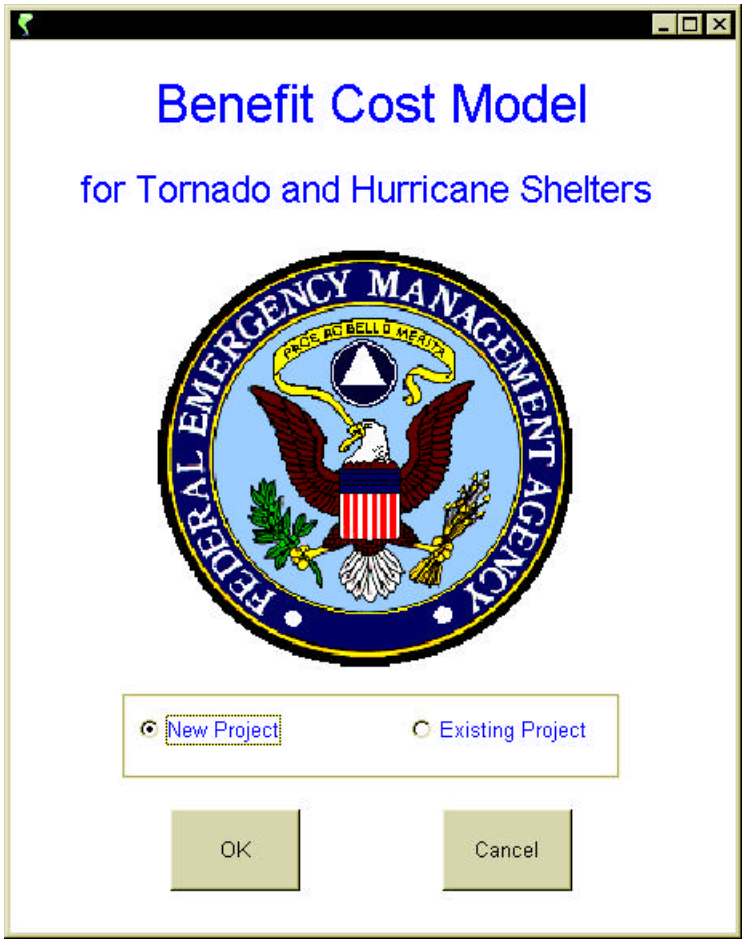
5. A window will indicate when the software has been uninstalled but it is possible that some items could not be removed. It is recommended that you complete the uninstall by manually deleting the folder containing the files. Be sure to restart the machine before attempting to reinstall the software.

3 Program Basics

This chapter will provide an overview of the screens, menus, and navigation buttons used in the Model. Chapter 4 will provide a tutorial for using the Model to create a tornado and hurricane shelter mitigation project file.

To start the model, click the Windows Taskbar *Start* button. Select *Programs* and then *Tornado and Hurricane Shelter Mitigation*. Finally, select *Benefit Cost Model*.

After starting the program, the opening screen will appear:



This screen allows the user to start a new project or open an existing project. The next section describes the program screens that allow operation of the program.

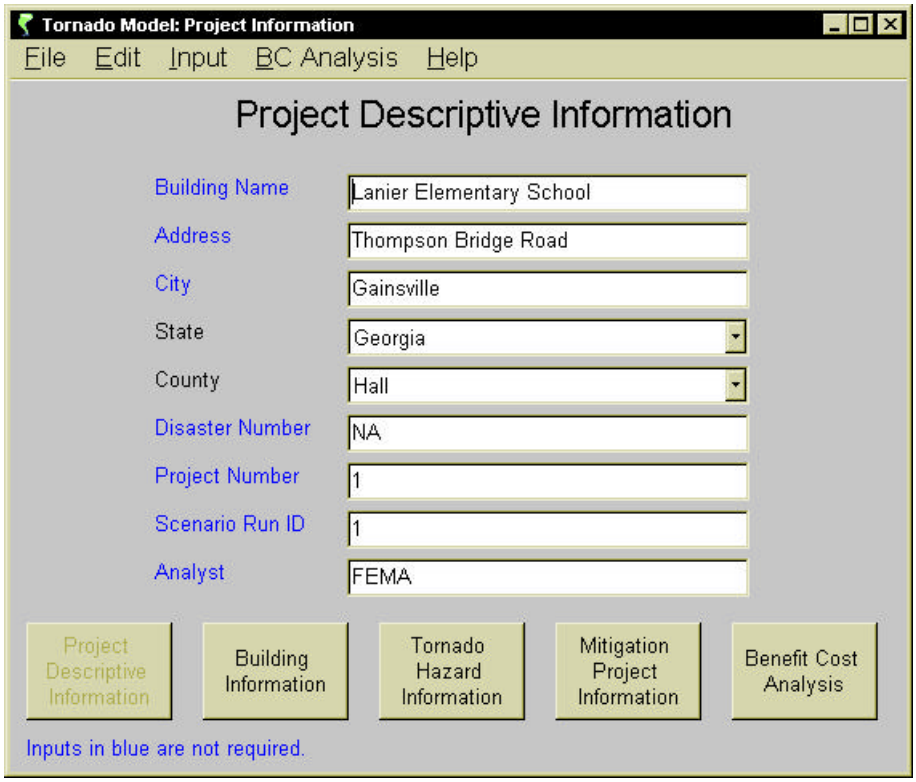
3.1 Program Screens

This section provides an overview of the main program screens, their functions, and the data required. Chapter 5 provides details about gathering the information

required for all program screens. Throughout the application, all fields are required except those with blue labels.

3.1.1 Project Descriptive Information

Once the user has selected a new project or an existing project on the opening screen, the *Project Descriptive Information* screen will appear.

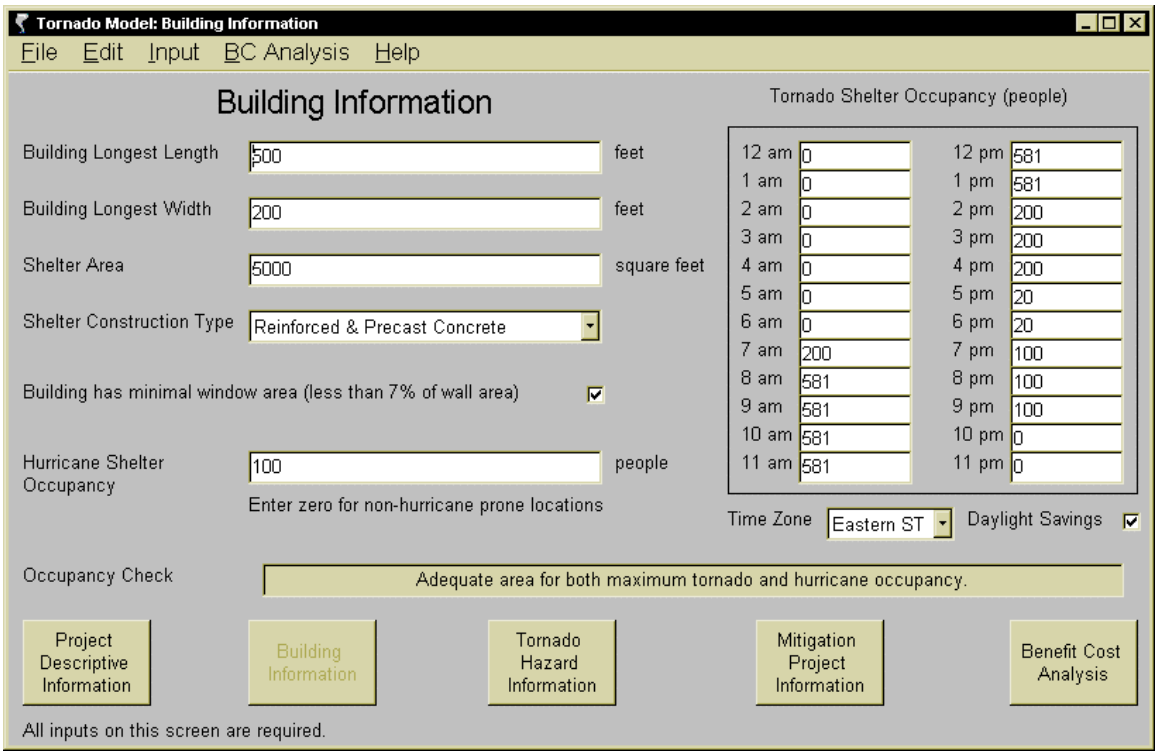


The *Project Descriptive Information* screen asks for basic information about the shelter. The most important item in this screen is the selection of a state and county. The program covers all 50 states and the District of Columbia, Puerto Rico, the Virgin Islands, American Samoa, and Guam. The model only requires that the user select a state and a county.

Along the top of the screen there is a menu that controls project files, report generation, and navigation. Along the bottom are the navigation buttons. Section 3.2 presents details about the menus and navigation buttons. Dimmed navigation buttons indicate the screen being displayed. The *Benefit Cost Analysis* button and menu will only become active when all of the required data has been entered. Menu items that are not active also appear dimmed.

3.1.2 Building Information

Once the user has entered the *Project Descriptive Information*, a navigation button or menu item will then load the *Building Information* screen.



The *Building Information* screen asks for information about the shelter, dimensions and construction type, and the occupancy of the shelter during tornado and hurricanes. All fields on this screen must have a value entered.

The building length and width are used to estimate the exposure to tornadoes. The shelter area corresponds to that section of the building retrofitted to withstand high winds. This area may be less than or equal to the building footprint area but cannot exceed it. Exposure computations are described in Chapter 5.

The shelter construction can be any of five standard types and a general type:

- reinforced and precast concrete
- reinforced masonry
- unreinforced masonry
- steel
- wood
- user defined

Damage functions for death and injury have been provided as defaults for these construction types. The default values are listed in Chapter 5. The user must carefully examine these damage functions to ensure that they represent conditions in the structure being analyzed. A sixth category labeled *User Defined* has been provided for buildings that do not fall into any of the standard types. The user must supply the damage functions when this type is selected.

The default damage curves also depend on the surface area of the building envelope covered by windows. If the windows account for more than 7 percent of the surface area, the corresponding check box should be cleared.

Usually, hurricane occupancy can be predicted based on the maximum capacity of the shelter because hurricanes can be forecast well in advance for people to travel to the shelter. These people are assumed to remain in the shelter for the duration of the hurricane. In non-hurricane regions, the hurricane occupancy should always be set to zero, since the shelter will only be used against tornado hazards.

The unpredictability of tornadoes makes it likely that the people in the building at the time the tornado occurs will be the ones to head for the shelter. Therefore, the shelter occupancy is equal to the building occupancy, which may vary hourly.

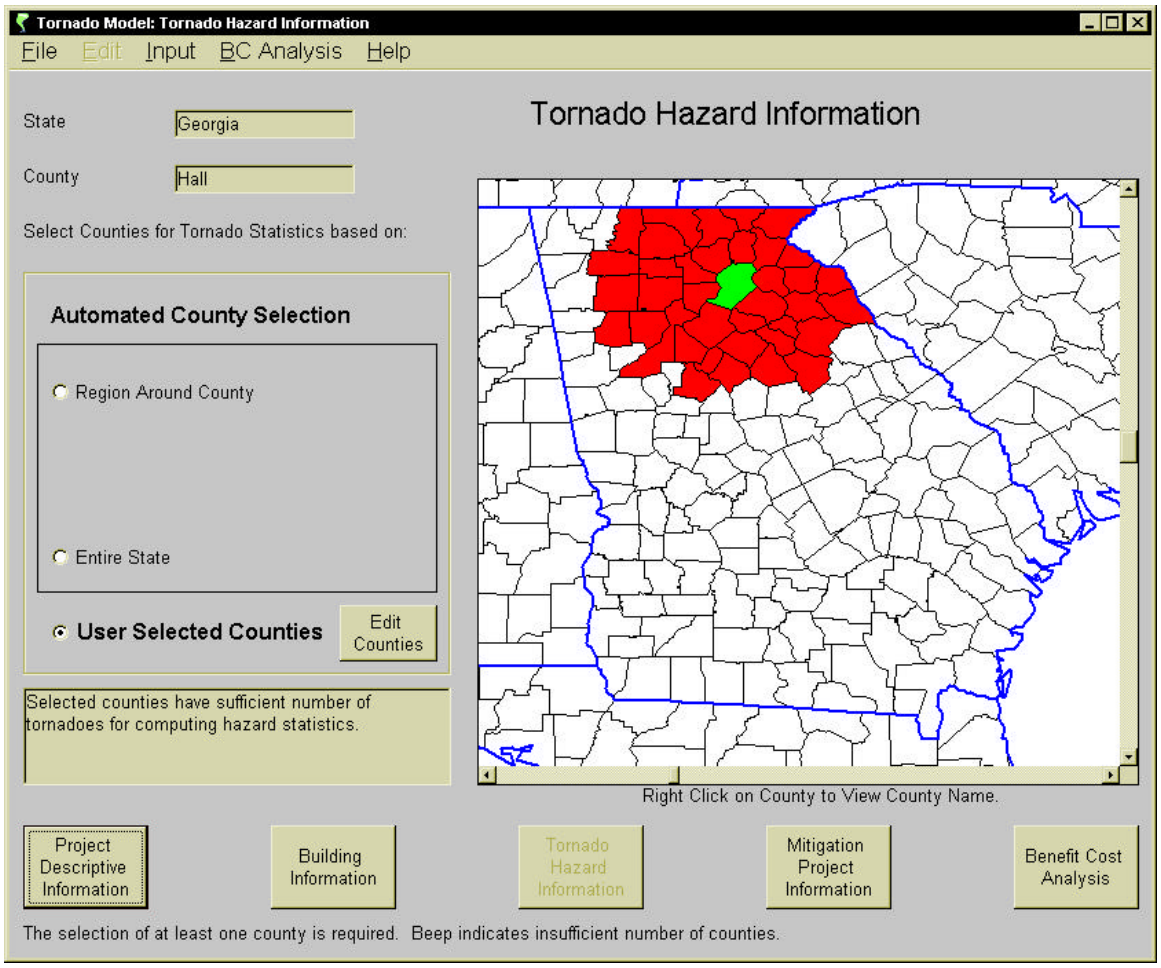
The *Occupancy Check* status box indicates whether the hurricane and tornado occupancy exceeds shelter area standards of 5 square feet per person during a tornado and 10 square feet per person during a hurricane.

3.1.3 Tornado Hazard Information

After the building information has been entered, the user can navigate to the *Tornado Hazard Information* screen shown on the next page.

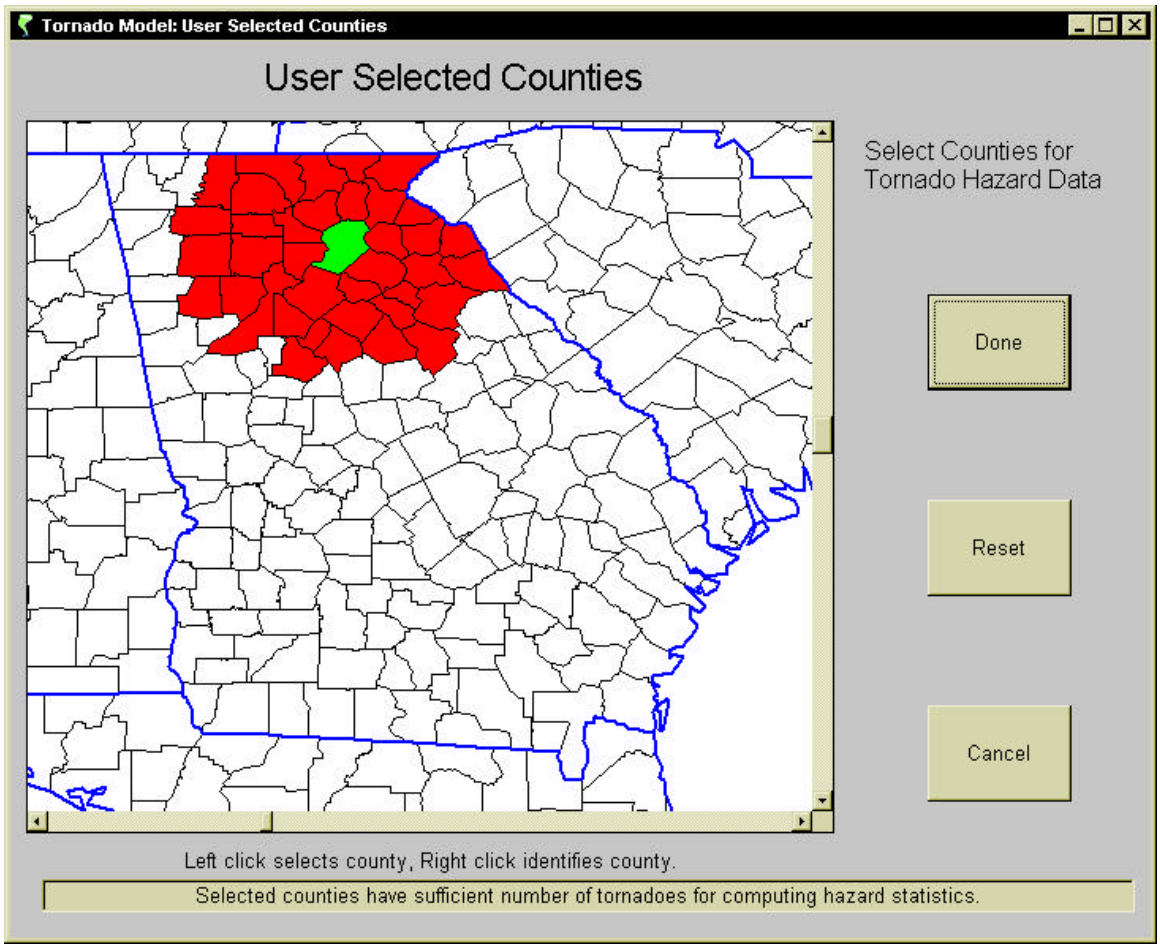
For the program to calculate the probability of tornado occurrence in the selected region, the database must have a sufficient number of past tornadoes. Because tornadoes are infrequent events, it is unlikely that a single county will have experienced a sufficient number of tornadoes for meaningful statistics. Therefore, the sample area must typically be comprised of several counties around the target county.

The *Tornado Hazard Information* screen allows the user to select a group of counties using three different methods as explained below. The target county is shown in green and is always part of the sample area. Other counties in the statistical sample area are shown in red. The user can right-click on any county to view its name. The status box below the selection options indicates whether the group of counties has a sufficient number of past tornadoes to compute tornado statistics.



Region Around County allows the user to select a given radius around the target county. All counties within that radius will be used as the sample area. *Entire State* selects all of the counties in the state of interest. *User Selected Counties* allows the user to select individual counties, and can also be used to modify areas selected with the other two methods. The sample area cannot be modified by clicking on individual counties in this screen.

When the *Edit Counties* button corresponding to the *User Selected Counties* option is pressed, the following screen appears.



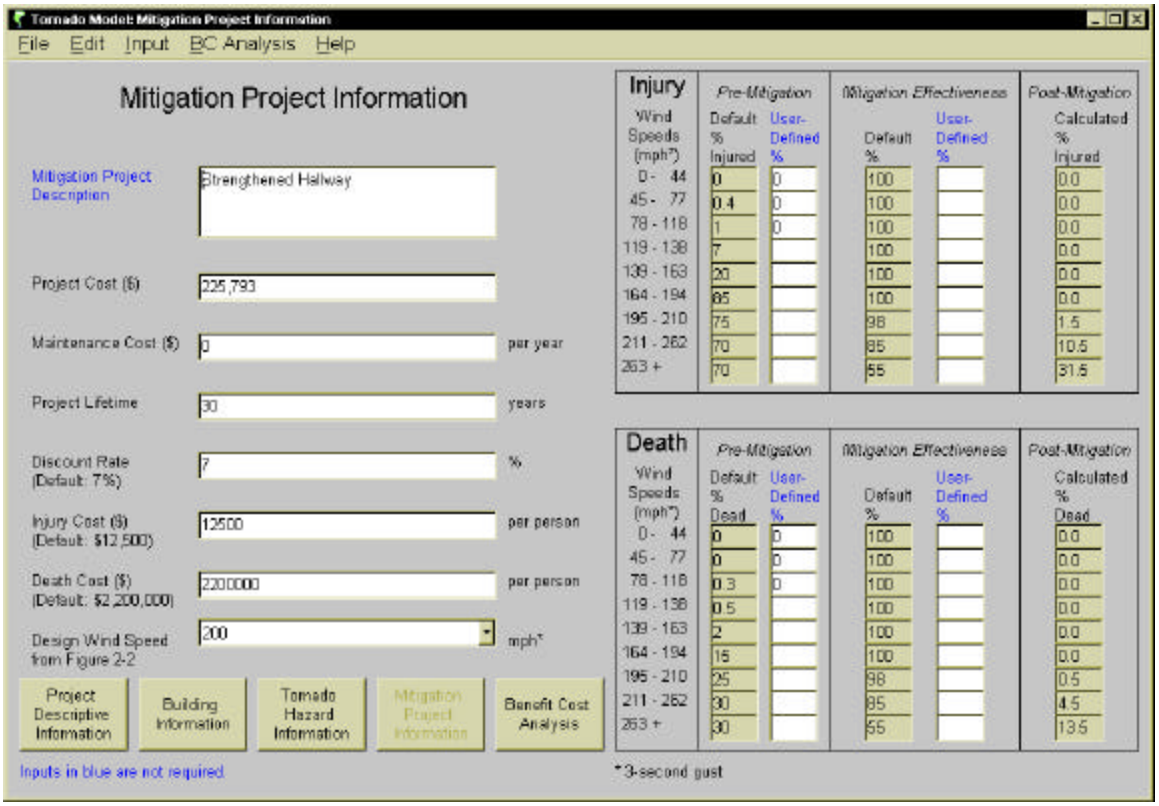
The user can click on individual counties to add or remove them from the statistical sample area. Clicking on white counties adds them to the sample area. Clicking on red counties removes them from the sample area.

The changes are confirmed or ignored using the three buttons to the right. *Done* returns to the *Tornado Hazard Information* screen with the new county selection. *Reset* clears all counties except the target county. *Cancel* ignores changes and returns to the *Tornado Hazard Information* screen.

Like the *Tornado Hazard Information* screen, the *User Selected Counties* screen also contains a status box that indicates when a sufficient number of counties has been selected.

3.1.4 Mitigation Project Information

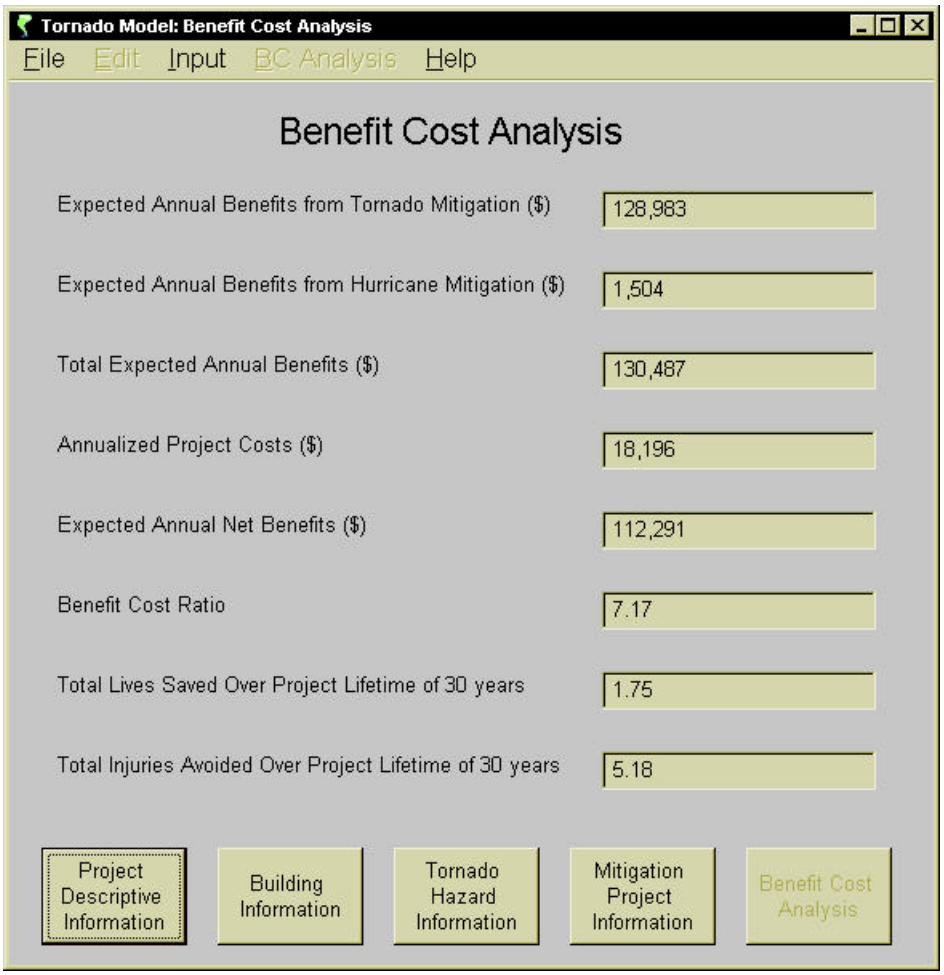
The *Mitigation Project Information* screen asks for the costs associated with the mitigation project, along with the project lifetime and discount rate. The user also enters monetary values for injuries and deaths, since the program determines benefits based on reduction of injuries and deaths. Default values are provided as explained in Chapter 5.



The pre-mitigation default values are based on the construction type selected on the *Building Information* screen. The mitigation effectiveness indicates what percent of pre-mitigation injuries and deaths will be avoided by implementing the proposed mitigation. Default values for mitigation effectiveness are based on the Design Wind Speed selected from the provided drop-down list. Figure 2-2 in the FEMA publication 361 *Design and Construction Guidance for Community Shelters* contains a map with the design wind speeds for the U.S. This map is also on page 16 of the Evaluation Checklists *pdf* file that was installed with the model (see Section 2.2 for the location of this file). The program uses the effectiveness to calculate post-mitigation injuries and deaths. The user can override any of the defaults by entering other values in the corresponding column.

3.1.5 Benefit Cost Analysis

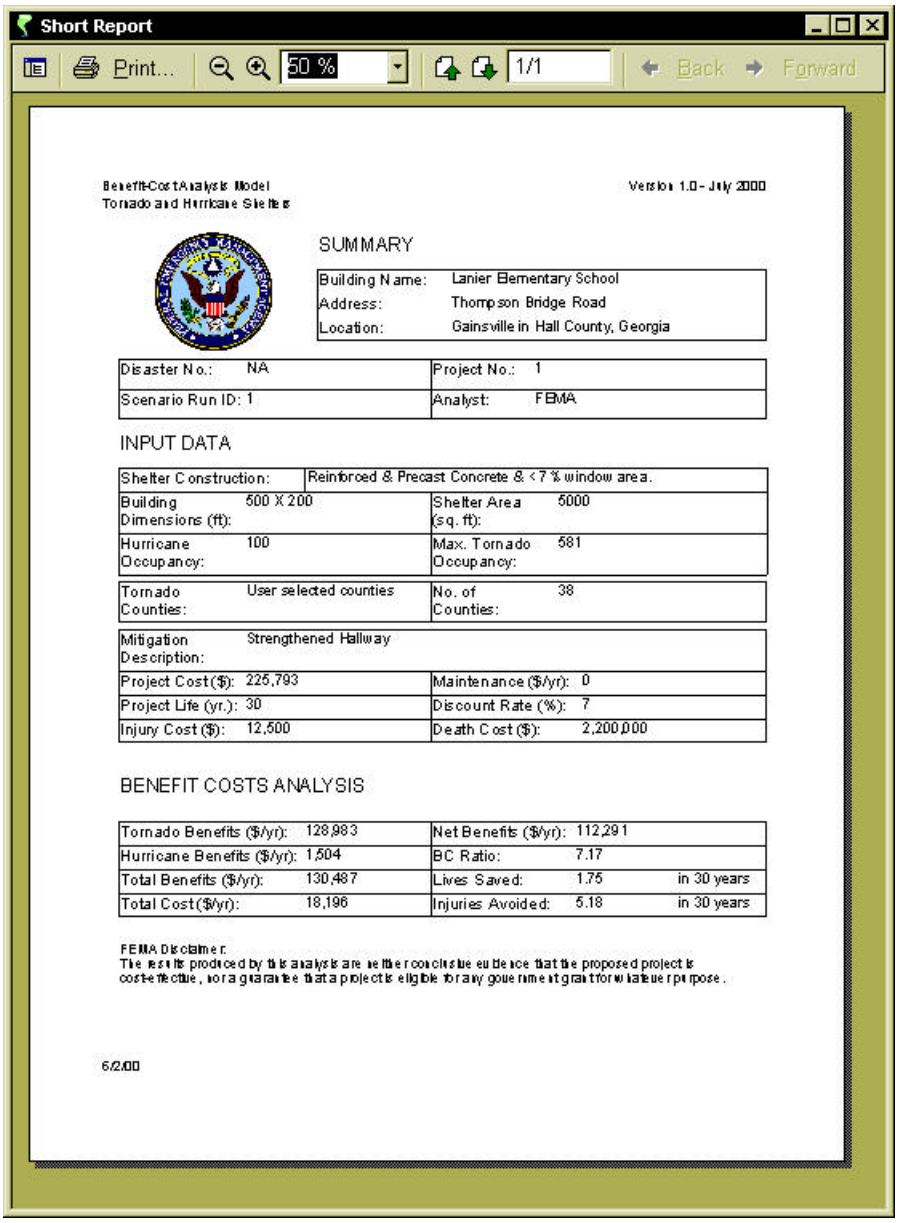
Once all of the required information has been entered, both the navigation menu and button that invoke the *Benefit Cost Analysis* screen become active.



This screen requires no user input and displays the results of the benefit-cost analysis. The screen shows the expected annual benefits of the mitigation for tornadoes and hurricanes. Annualized project costs are calculated, based on the project lifetime and discount rate. The expected annual net benefits are the difference between the benefits and the costs; a positive value indicates a cost-effective project. A Benefit Cost Ratio of 1.0 or greater is also indicative of cost-effectiveness. The expected number of deaths and injuries avoided over the project lifetime, due to the proposed mitigation, are also shown.

3.1.6 Short Report Print Preview

After a benefit-cost analysis has been performed, the *Print Preview* and *Print* items in the *File* menu become active. When *Print Preview*, *Short Report* is chosen, the following screen is displayed.

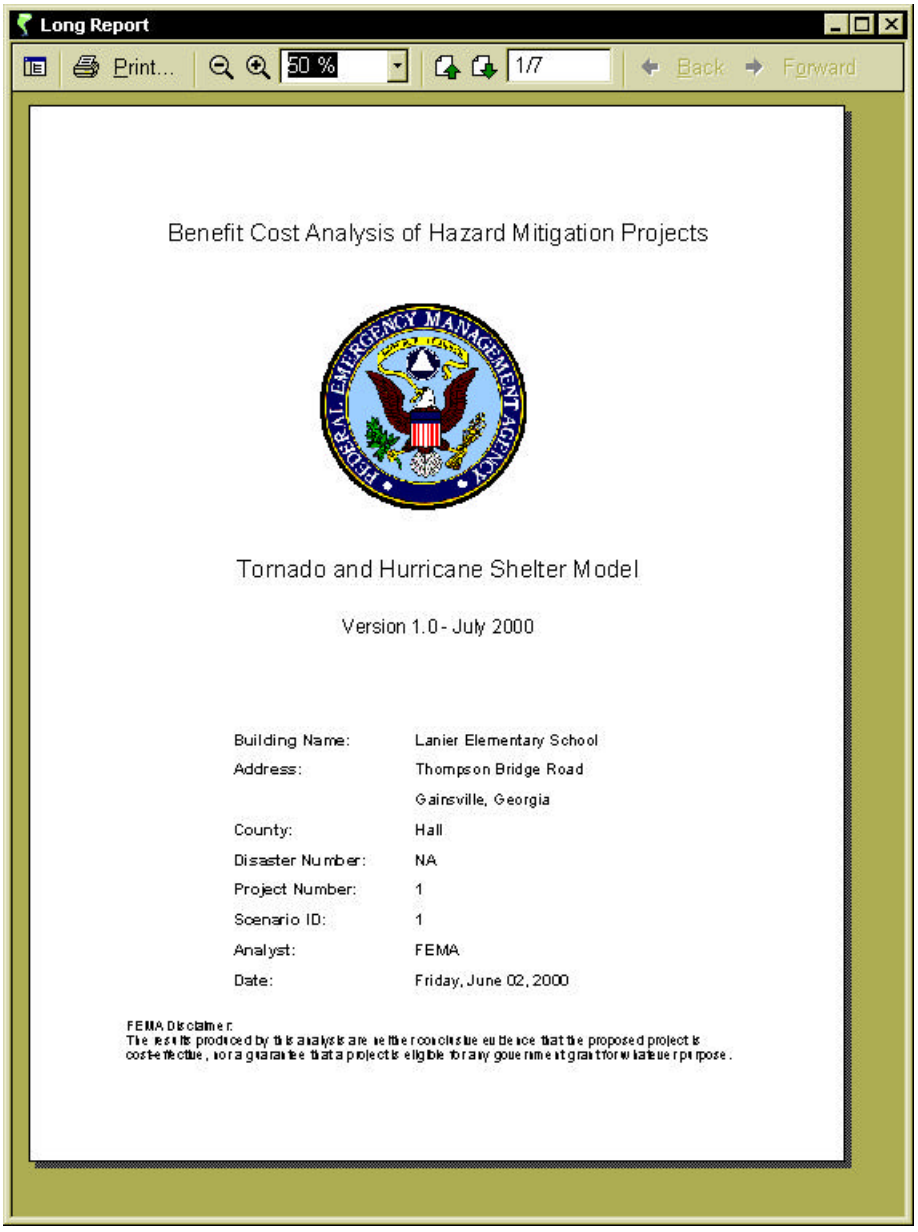


The short report is a one page summary of the inputs and results of the benefit-cost analysis. The print preview screen allows the user to view and print the report.

The tools associated with this screen will be explained in the next section.

3.1.7 Long Report Print Preview

When *Print Preview*, *Long Report* is chosen, the following screen is displayed.



The long report is a seven-page report giving detailed information about the program input data, the hazard statistics, and the results of the benefit-cost analysis. The print preview screen allows the user to view and print the report.

The toolbar along the top of the print preview screen allows the user to print the report, view the report at different magnifications levels, and navigate through the report pages.

From left to right, the first icon in the toolbar controls a table of contents (which is not used). The second icon, with the printer graphic and the word "*Print…*", activates the print command, which displays a screen where the user can select the printing options. The print screen also allows access to printer setup commands.

The next three icons control the magnification of the print preview. The + and – magnifying glass icons zoom in and out on the current page of the report. The drop box with percentages also controls the magnification of the current page.

The final five icons relate to navigation through a report and are only active for the long report. The page up and down arrow icons will cause the screen to go to the previous or next page in the report. The window next to these icons indicates the current page number and the total page number. Finally, the back and next buttons can also be used to navigate through the report pages.

The *Print Preview* screen can manually be resized or moved by clicking with the mouse on the screen border and dragging to the desired size or location. The screen can be closed by clicking on the X icon on the upper right corner of the screen.

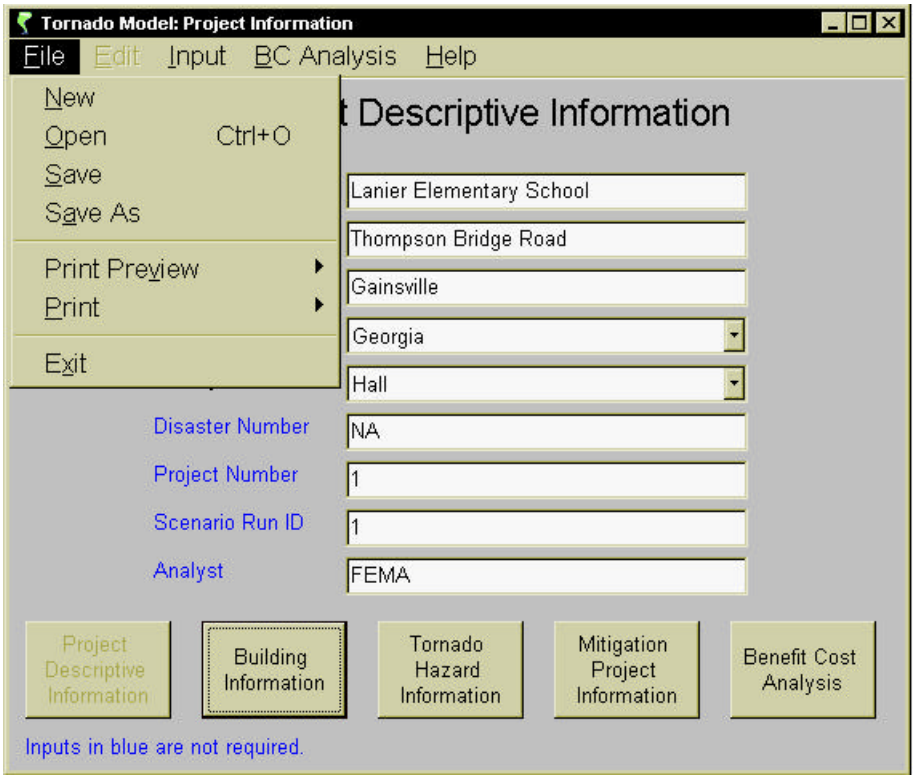
In addition, the screen can be resized, moved, or closed using the Window menu, which is activated by clicking on the tornado icon in the upper left corner of the screen (before the screen title). The Window menu is available on all screens in the model.

3.2 Commands and Procedures

This section details the menu items and navigation buttons included in the program.

3.2.1 File Menu

The *File* menu controls the files used to store the mitigation project information, allows the creation and printing of reports, and allows the user to exit the program.



New creates a new project file. After prompting the user to save the current project, all program screens will be cleared for the new project.

Open loads an existing project file. The program stores projects with the .tor extension. After prompting the user to save the current project, a browse window will open that allows the user to load a project file from any directory. The selected file will load and all screens will be updated with the selected file's information.

Save saves the current project file. If the file has previously been saved, Save will use the existing file name. If the file has not been saved before, the user will be prompted for a file name.

Save As prompts the user for a file name for the current project.

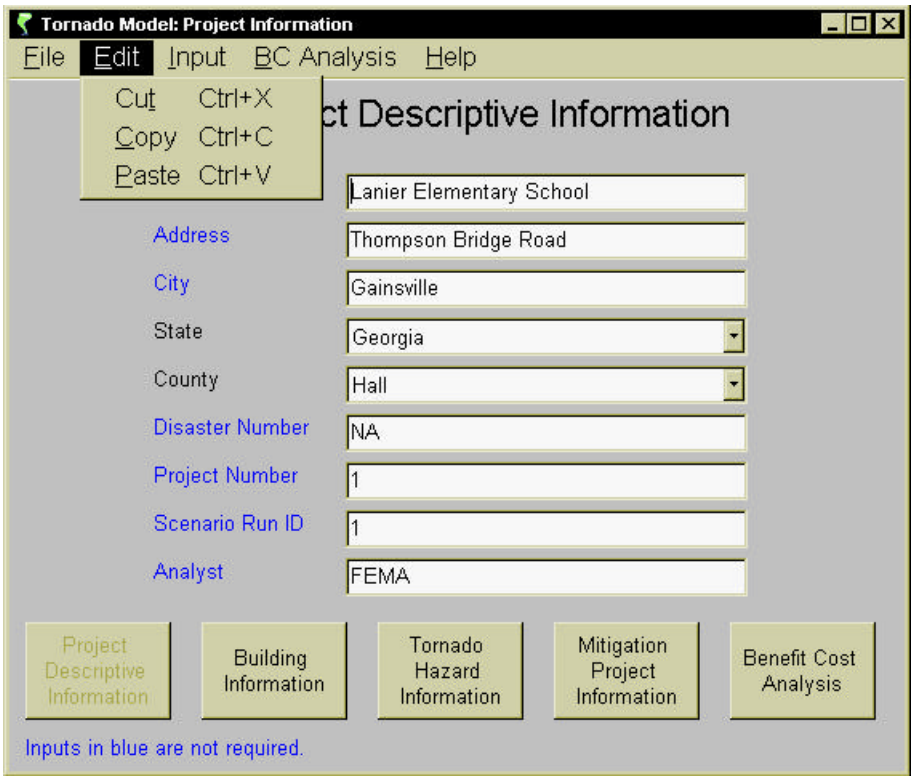
Print Preview allows the user to preview either the short or long format reports generated by the program after a benefit cost analysis has been performed. The reports can be printed from the preview window. The toolbar and Window menus in the print preview screens are described elsewhere in this document.

Print allows the user to print either the short or long format reports generated by the program after a benefit-cost analysis has been performed.

Exit will close the program after prompting the user to save the current project.

3.2.2 Edit Menu

The *Edit* menu allows the user to copy and paste text between the clipboard and the program inputs.



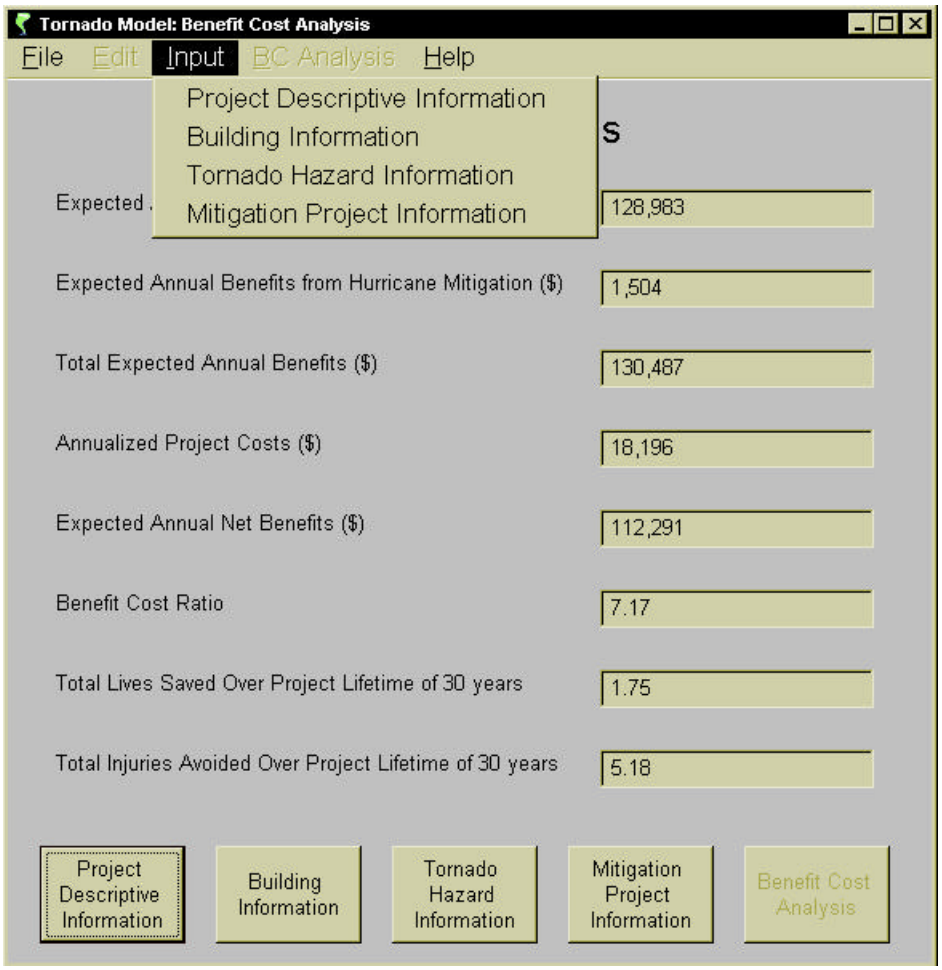
Cut deletes selected text from its current location and copies it to the clipboard.

Copy places selected text in the clipboard without deleting it from its location.

Paste places text currently in the clipboard into the selected location.

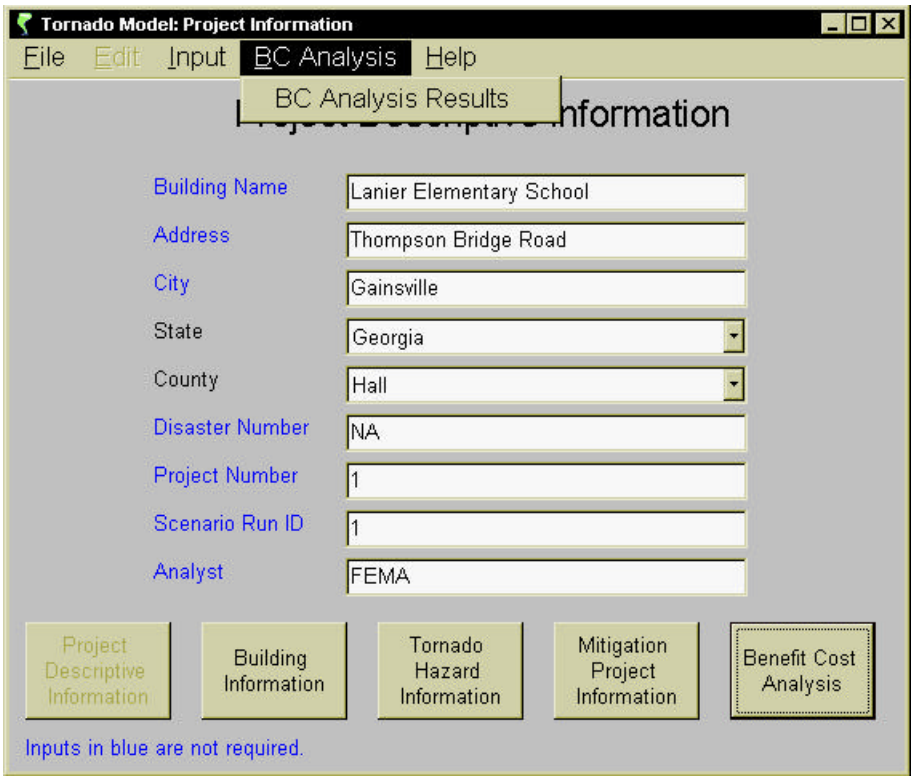
3.2.3 Input Menu

The *Input* menu provides navigation between the four input information screens described above. Selecting one of the four menu items switches the application to the corresponding screen.



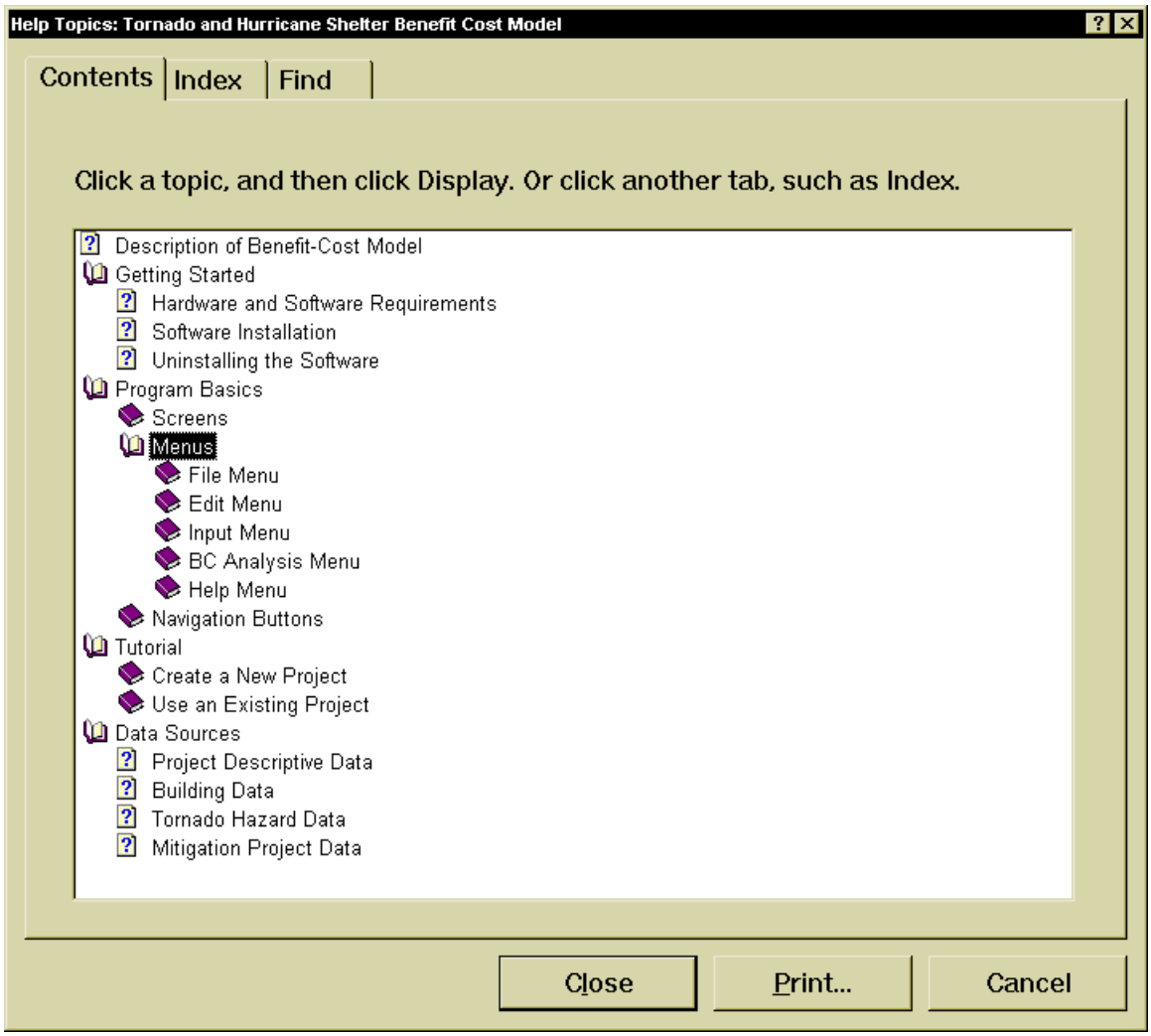
3.2.4 BC Analysis Menu

The BC Analysis menu contains one item only that provides navigation to the Benefit-Cost Analysis screen.



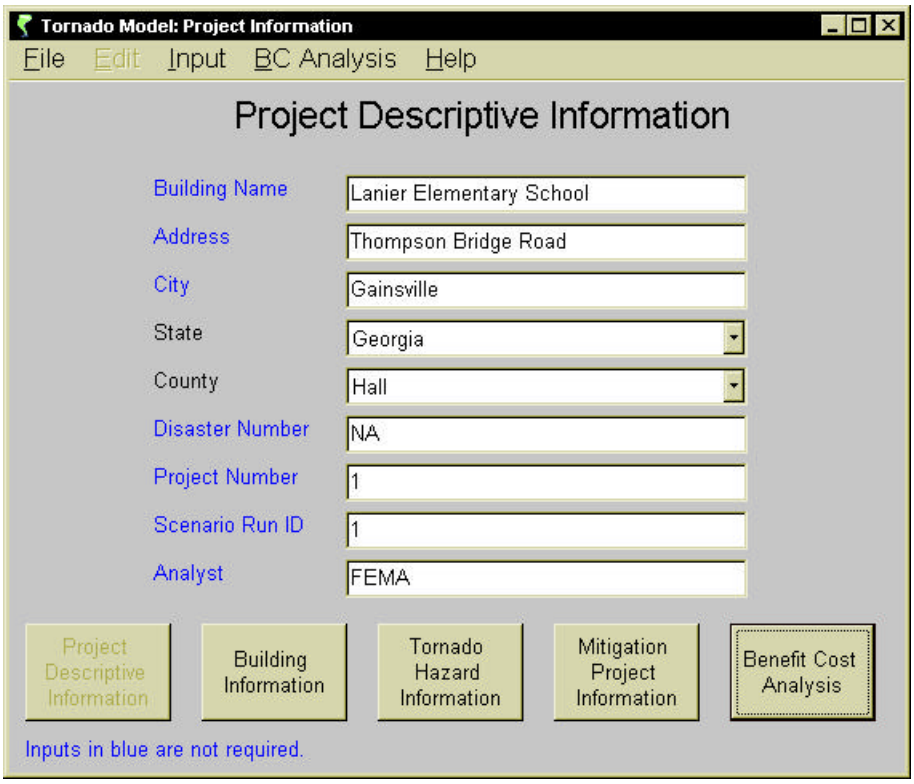
3.2.5 Help Menu

The Help menu loads the Help file for the program. Throughout the program, the F1 key loads topic-specific help.



3.2.6 Navigation Buttons

The Navigation Buttons are an alternate way to move between screens. The button for the active screen is dimmed. Clicking on any of the buttons switches to the corresponding screen. The *Benefit Cost Analysis* button is dimmed until all of the required information has been entered.



4 Tutorial

This chapter will provide step-by-step details for entering project information, performing a benefit-cost analysis, saving and retrieving a project file, and previewing and printing reports.

4.1 Creating a New Project

To start, click the Windows Taskbar *Start* Button. Select *Programs* and then *Tornado and Hurricane Shelter Mitigation*. Finally, select *Benefit Cost Model*.

Select *New Project* from the opening screen and click *OK*.

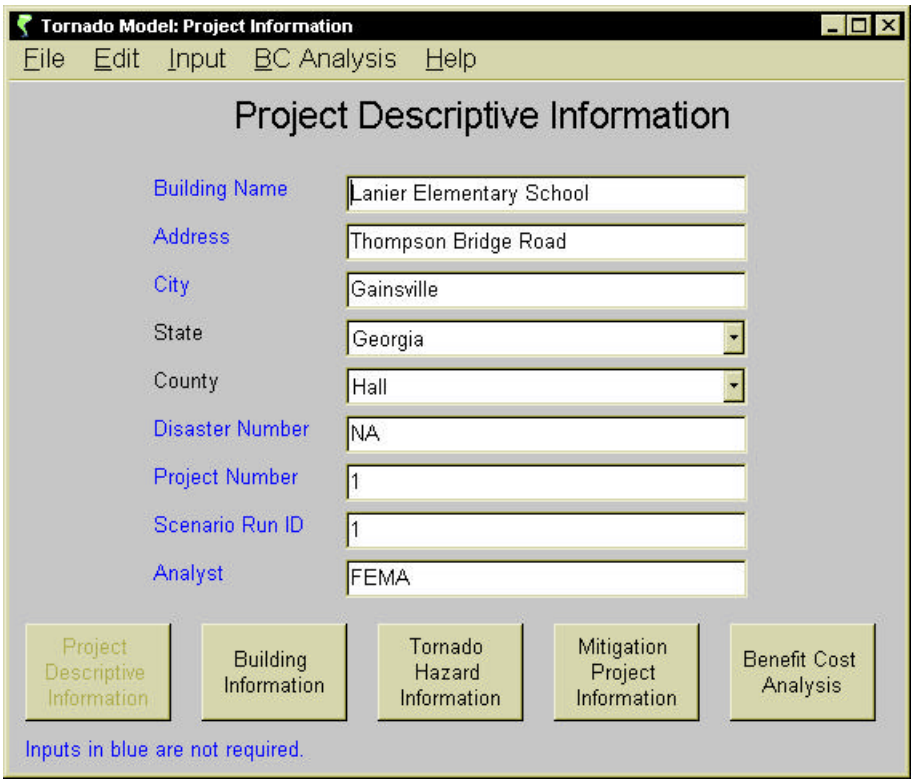
4.1.1 Project Descriptive Information

After the *Project Descriptive Information* screen is displayed, enter the information shown below. Use the mouse or tab key to navigate through the input fields.

Building Name	Lanier Elementary School
Address	Thompson Bridge Road
City	Gainsville
State	Georgia (Use drop-down list)
County	Hall (Use drop-down list)
Disaster Number	NA
Project Number	1
Scenario Run ID	1
Analyst	FEMA

Note that the county dropdown box will not contain any choices unless a state has been selected. The software will not allow switching to another screen unless a state and county have been selected.

The completed screen should look like the following:



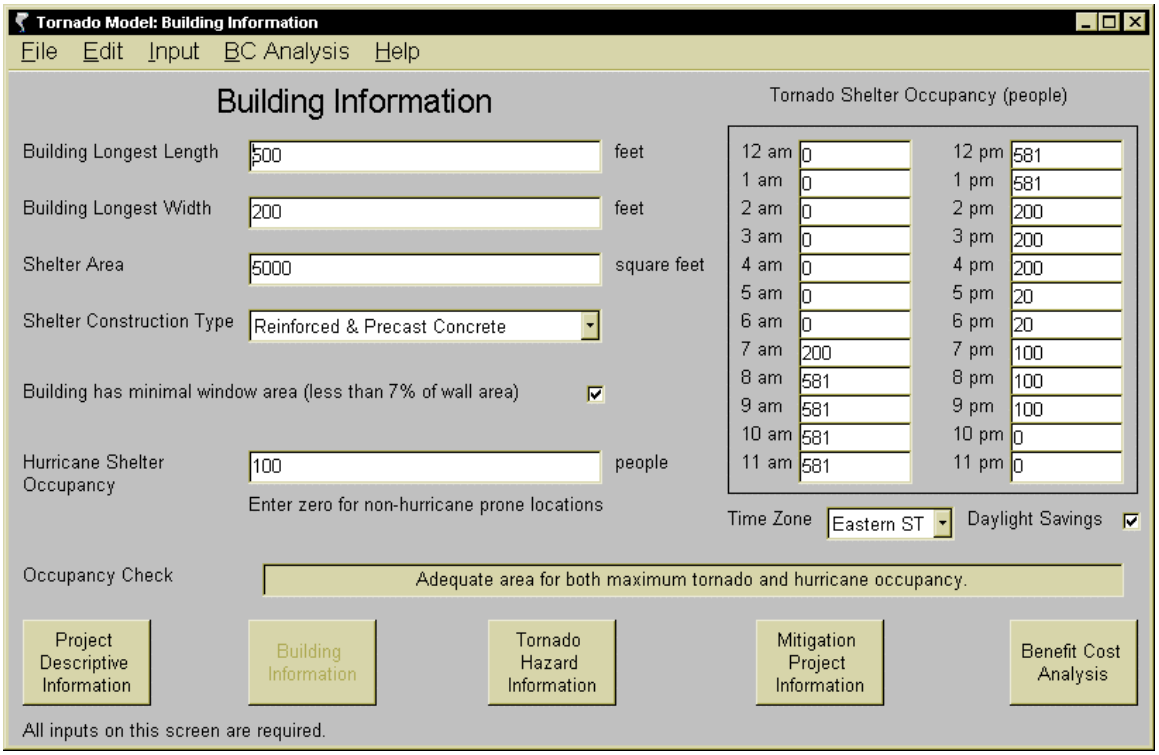
Click on the *Building Information* button to go to the *Building Information* screen.

4.1.2 Building Information

Enter the information shown below into the *Building Information* screen. The mouse or tab key will navigate through the input fields. As you enter the data, you will notice that the message in the *Occupancy Check* status box will change.

Building Longest Length	500 ft
Building Longest Width	200 ft
Shelter Area	5000 ft^2
Shelter Construction Type	Reinforced & Precast Concrete (Use drop-down list)
Checkbox for "Building has minimal window area (less than 7% of wall area)"	Checked
Hurricane Shelter Occupancy	100 people
Tornado Shelter Occupancy	0 for 12 am through 6 am 200 people for 7 am 581 people for 8 am through 1 pm 200 people for 2 pm through 4 pm 20 people for 5 pm through 6 pm 100 people for 7 pm through 9 pm 0 for 10 pm through 11 pm
Time Zone	Automatically chosen by program as Eastern ST
Checkbox for Daylight Savings	Automatically checked by the program

The completed screen should look like the following:

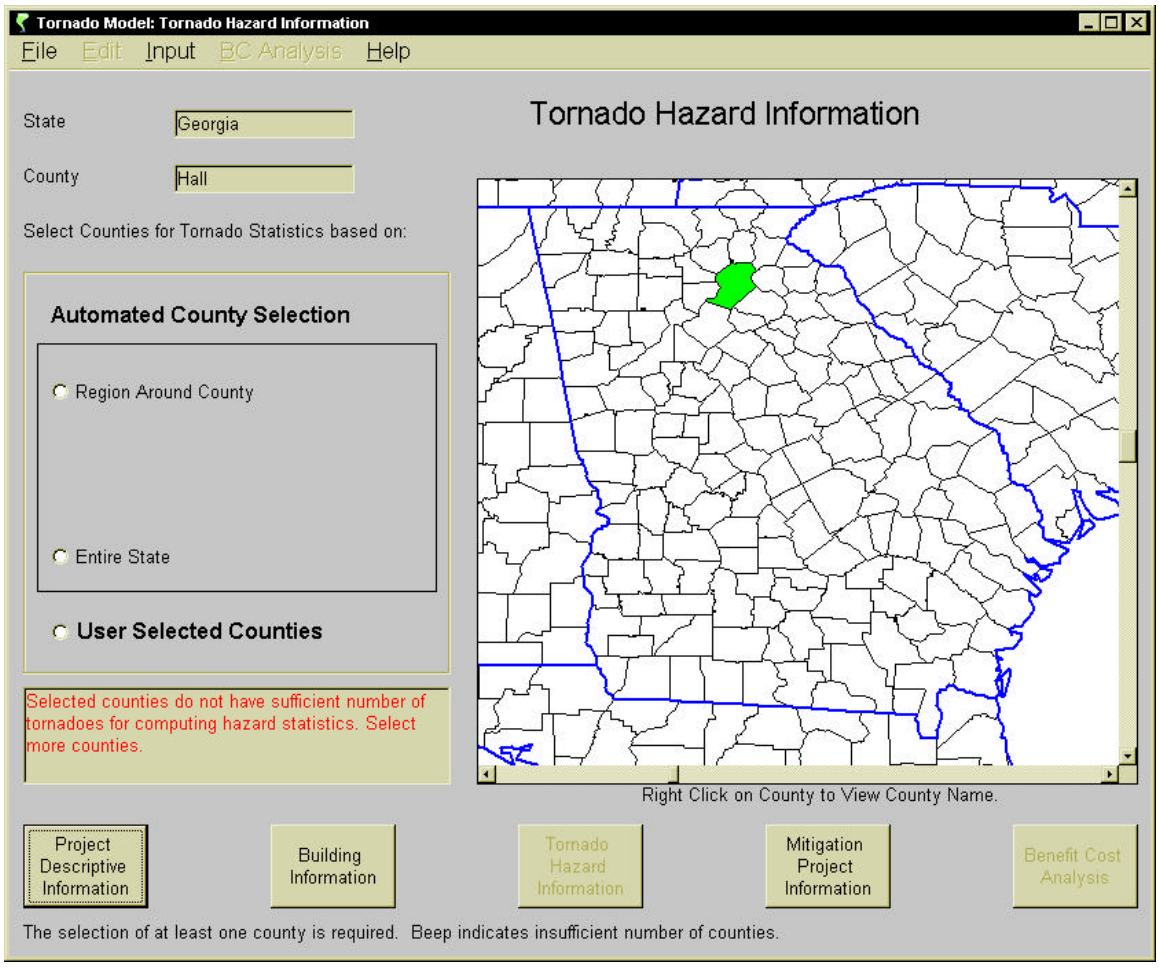


The status box will warn the user when the occupancy exceeds 5 ft^2/person for tornado shelters or 10 ft^2/person for hurricane shelters.

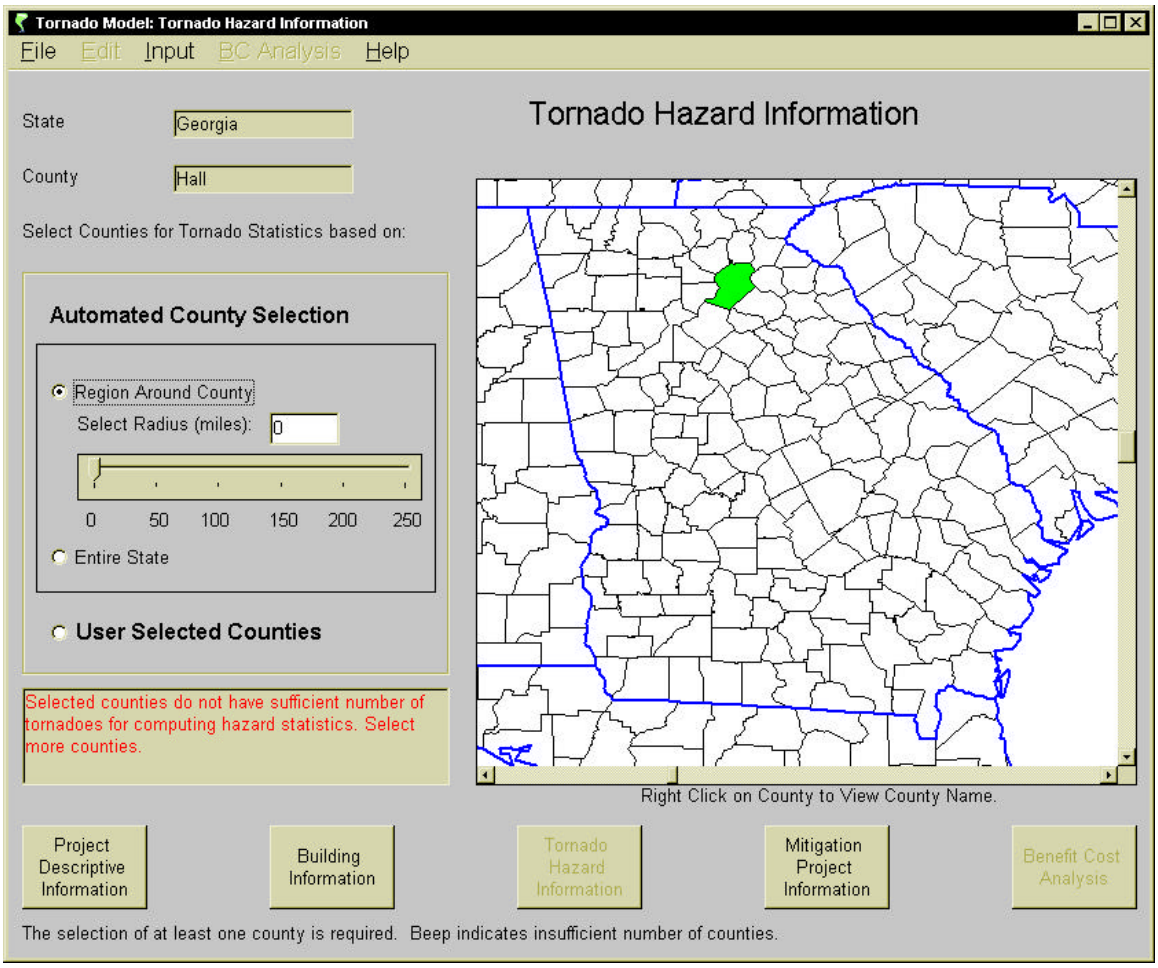
Click on the *Tornado Hazard* button to go to the *Tornado Hazard Information* screen.

4.1.3 Tornado Hazard Information

When you first enter this screen, only Hall County will be selected (shown in green) and none of the county selection options will be active. The computer will beep whenever the selected counties do not have a sufficient number of tornadoes to compute hazard probabilities.

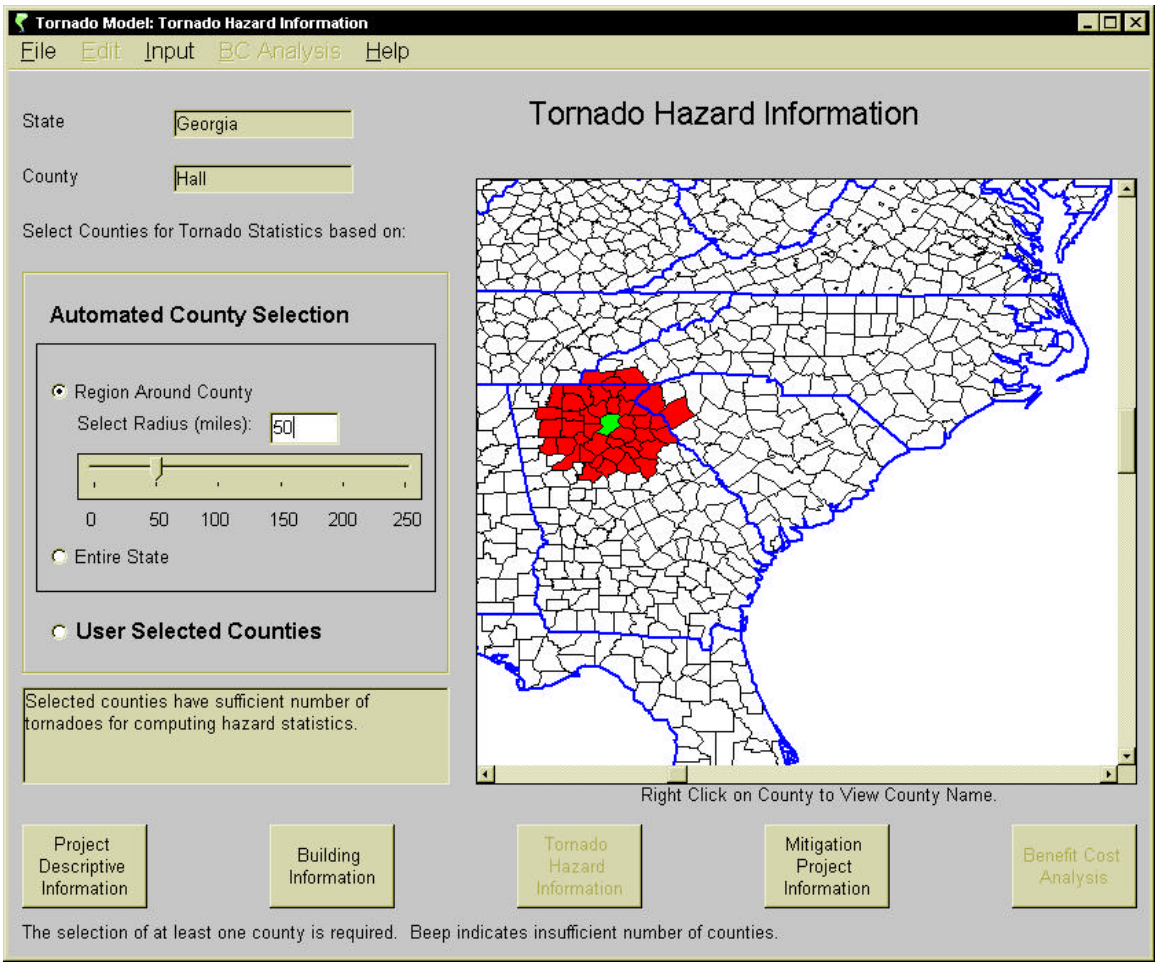


Click on *Region Around County*. A slider bar and text box will appear to select a region around Hall County from which tornado statistics will be derived. In the majority of cases, one county alone has not experienced enough tornadoes to calculate meaningful statistics.



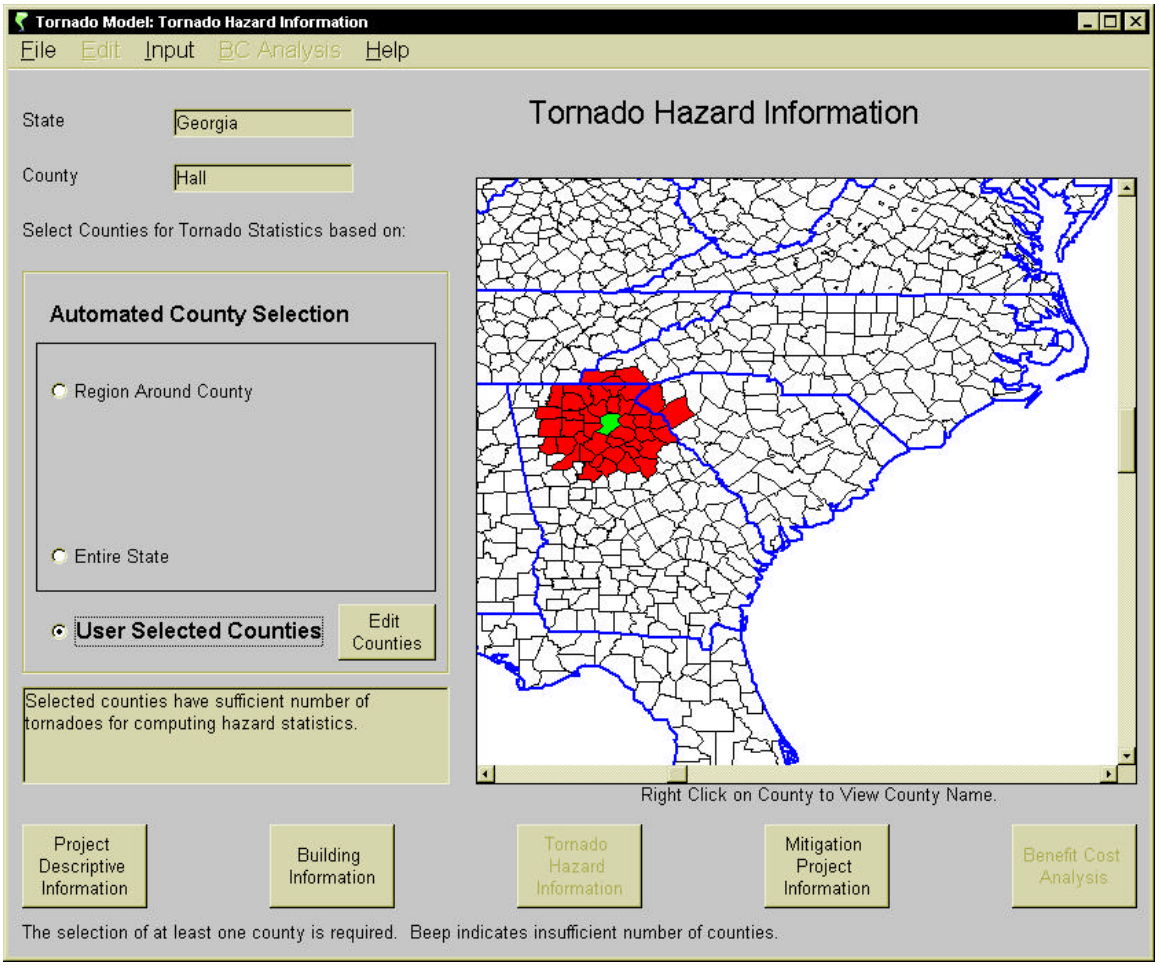
Click on the slider bar once or drag it to advance the radius from 0 to 50 miles. You can also type the radius value in the text box and hit *Enter*. After this is done, you will need to wait a few moments while the program queries the national tornado database determines if the selected counties have sufficient tornado occurrences for statistical analysis. The status box will read "Calculating" until the selection and calculation are complete.

The screen should look like the figure shown below. Notice that the newly selected counties are in red, while Hall County remains green. Also notice that the map scale resets to show Georgia, South Carolina, and North Carolina, since the selected counties fall within these states.

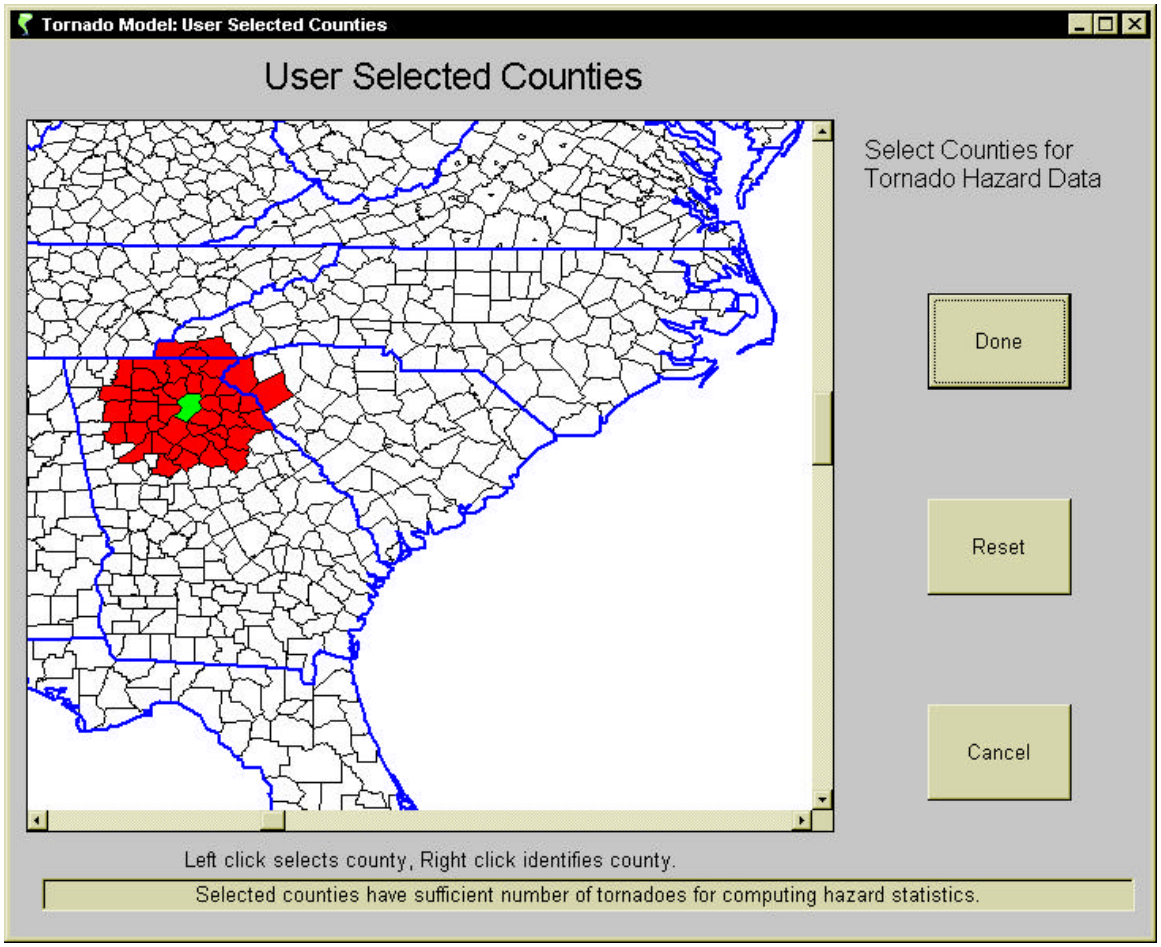


Clicking *User Selected Counties* allows manual addition or deletion of counties to the statistical sample area. This option is seldom used. Unless there are site-specific conditions that justify modifying the selection, the user should let the software select counties according to a specified radius. If modified, the selection should be such that the counties in the sample area are all contiguous. Chapter 5 provides additional information on when the manual option should be invoked.

After clicking *User Selected Counties*, the *Edit Counties* button becomes visible as shown in the next figure.

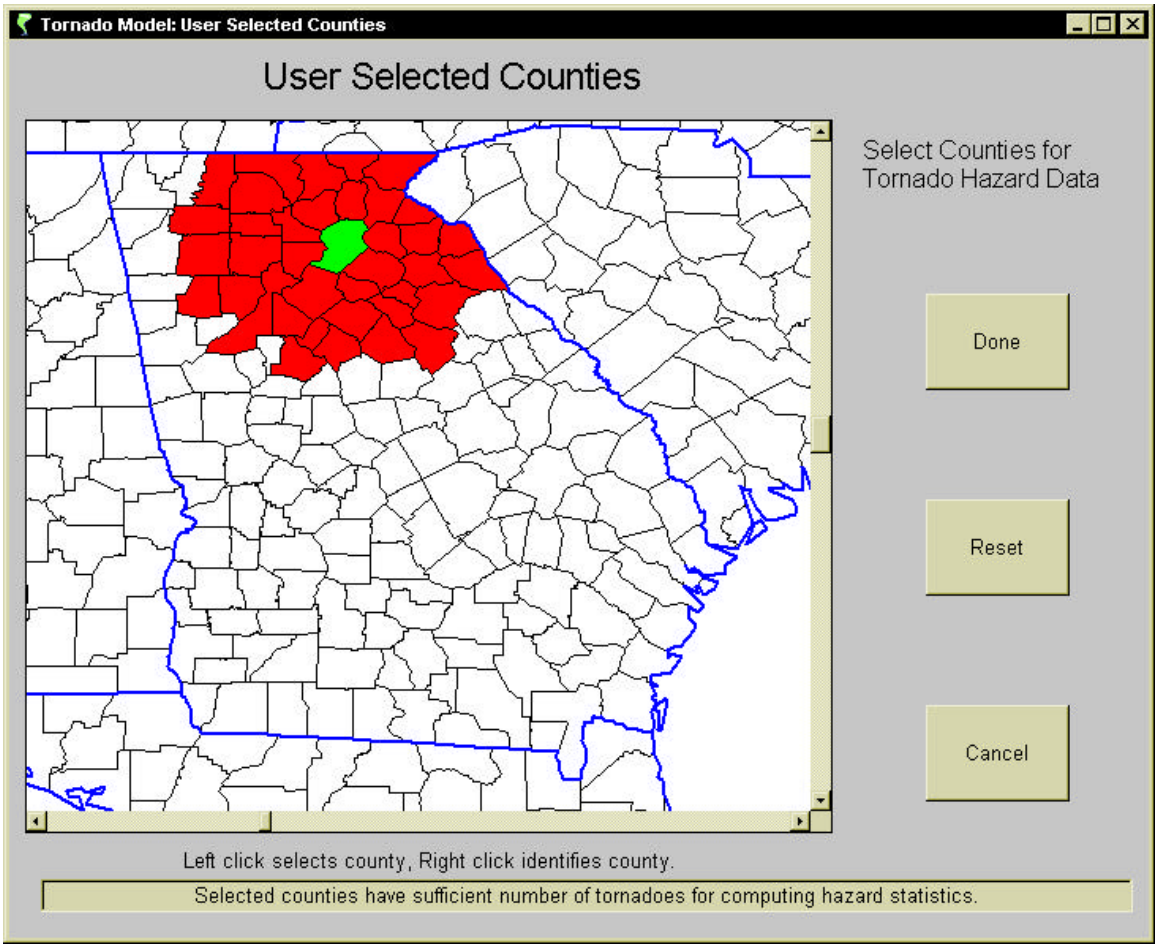


For this tutorial, assume that you only want to use counties in Georgia. To remove the counties in other states, click the *Edit Counties* button. The *User Selected Counties* screen should appear as shown below. This screen allows you to add or remove individual counties.



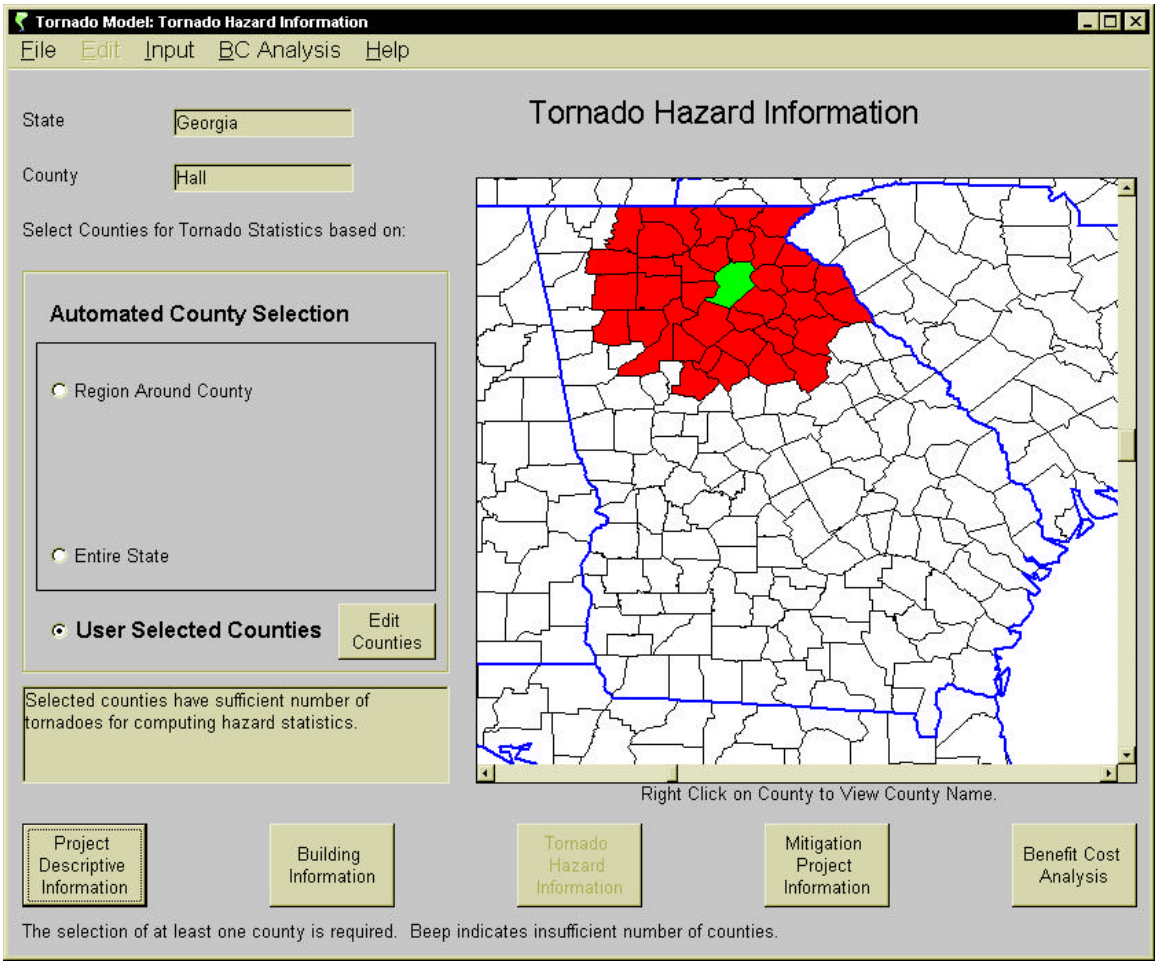
Using the mouse, left click on the red counties that are not in Georgia. As you click on these counties, they will change from red to white and the status window will show whether sufficient tornadoes remain in the sample area to compute statistics. Clicking on white counties will add them to the selected region.

When you have removed all counties not in Georgia, the view will zoom in to only Georgia and look like the screen shown below.



To keep these selected counties, click the *Done* button to return to the *Tornado Hazard Information* screen. The *Reset* button deselects all counties except Hall County. The *Cancel* button closes this window and returns to the *Tornado Hazard Information* screen with the selection unchanged.

When you return to the *Tornado Hazard Information* screen, the map will be identical to the one you created on the User Selected Counties screen and should look like the screen shown below.



Now that you have selected your counties for tornado statistics, click the *Mitigation Project Information* button to go to that screen. A popup window with a progress bar indicates that tornado statistics are being extracted from the tornado database.

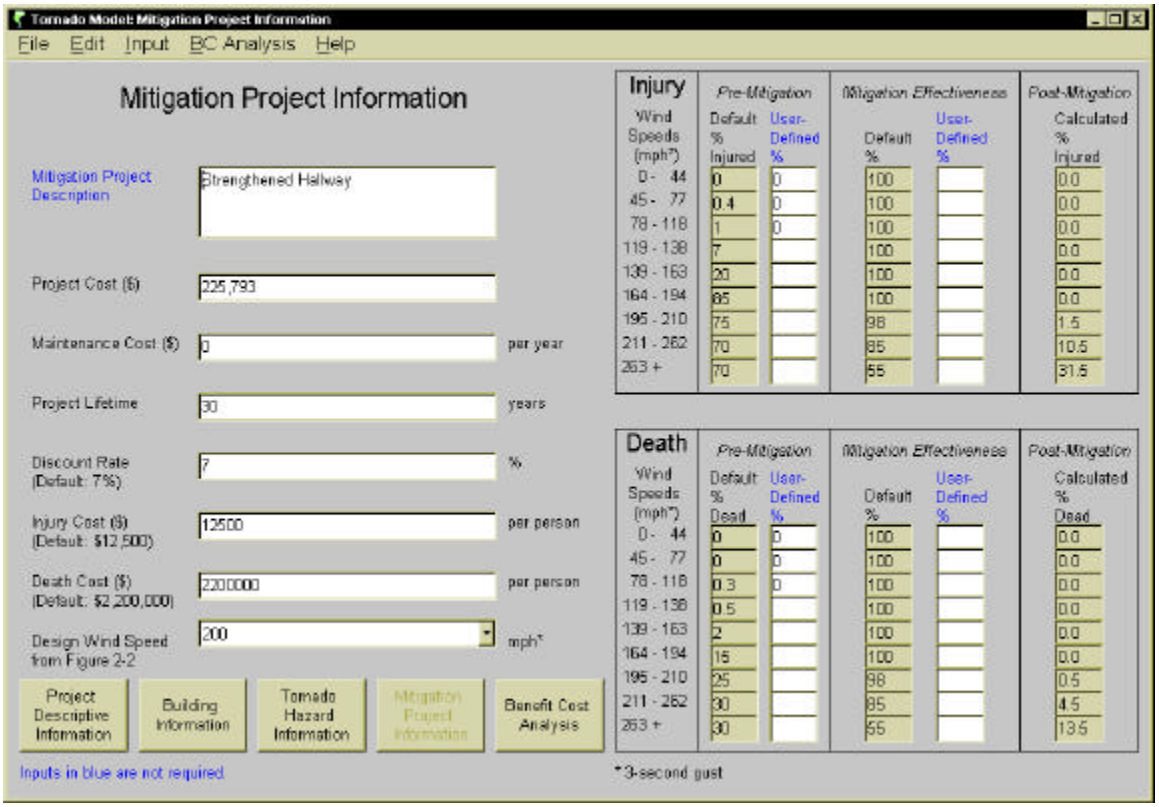
4.1.4 Mitigation Project Information

In the *Mitigation Project Information* screen, enter the following information:

Mitigation Project Description	Strengthened Hallway
Project Cost	$225,793
Maintenance Cost	$0 (Default)
Project Lifetime	30 years
Discount Rate	7 % (Default)
Injury Cost	$12,500 / injury (Default)
Death Cost	$2,200,000 / death (Default)
Design Wind Speed	200 mph
User-Defined Pre-Mitigation Injury and Death Curves	Enter 0 only in the first 3 wind ranges for injury and death.

Default values will be used for all other pre-mitigation and mitigation effectiveness boxes that are left blank. This input assumes that the building withstands a wind speed of up to 118 mph in its current state; therefore, no deaths or injuries are expected.

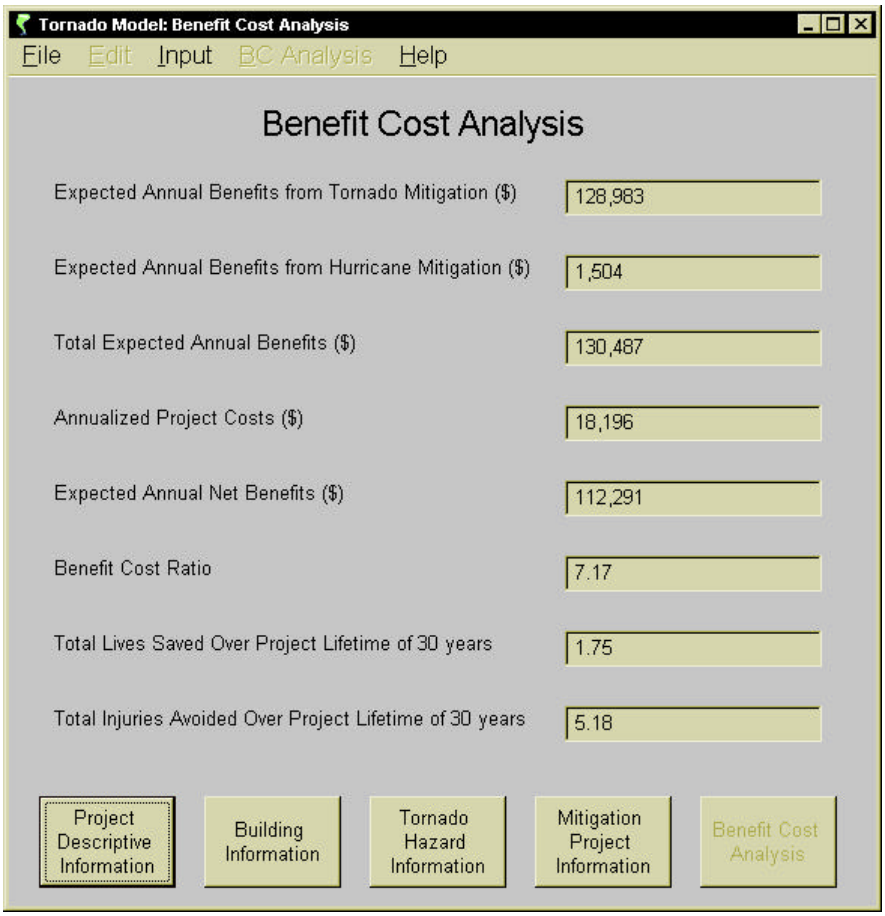
After the data has been entered, the screen should look like the figure below.



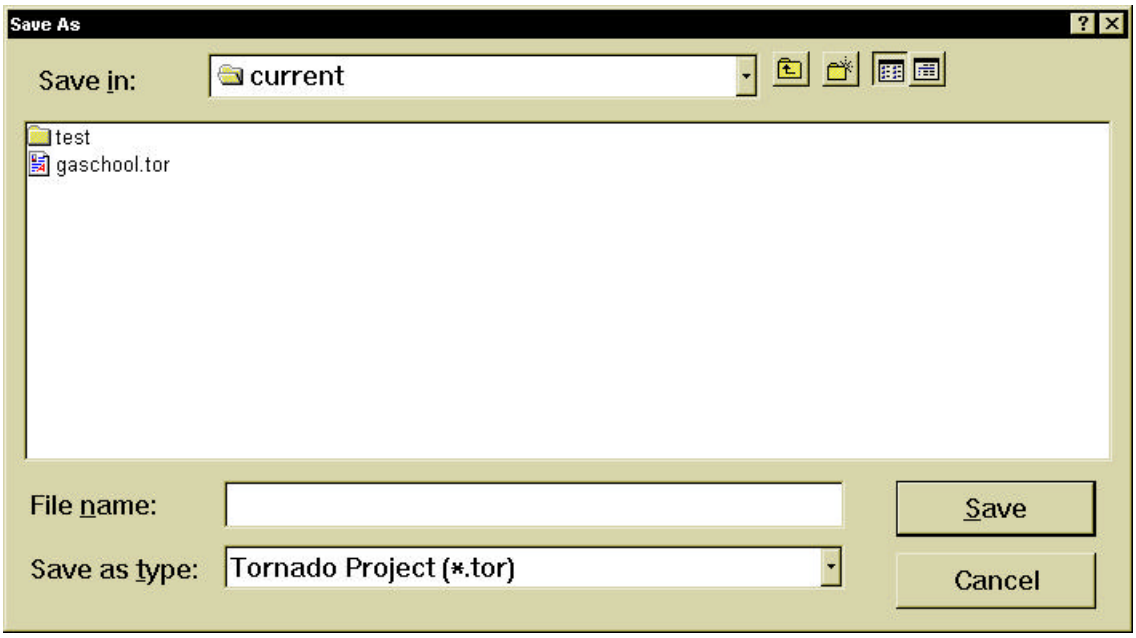
This screen contains several default values. When you enter a value for the *Project Lifetime*, the *Benefit Cost Analysis* button and menu become active. This indicates that all of the data necessary to perform a benefit-cost analysis have been entered. Click the *Benefit Cost Analysis* button to perform the benefit cost analysis.

4.1.5 Benefit Cost Analysis Results

After a brief pause for calculation, the *Benefit Cost Analysis* screen will show the results of the analysis. For the project data entered, the project is cost-effective, with a Benefit Cost Ratio of 7.17 and an Expected Annual Net Benefit of $112,291.



To save the project just created, click on the *File* menu and select *Save* to open the form shown below.



Navigate to the directory of your choice and in the *File name* box, enter a name for the file. The program will save the project as *<your_file_name>.tor*.

You have now successfully entered and saved a tornado and hurricane shelter project!

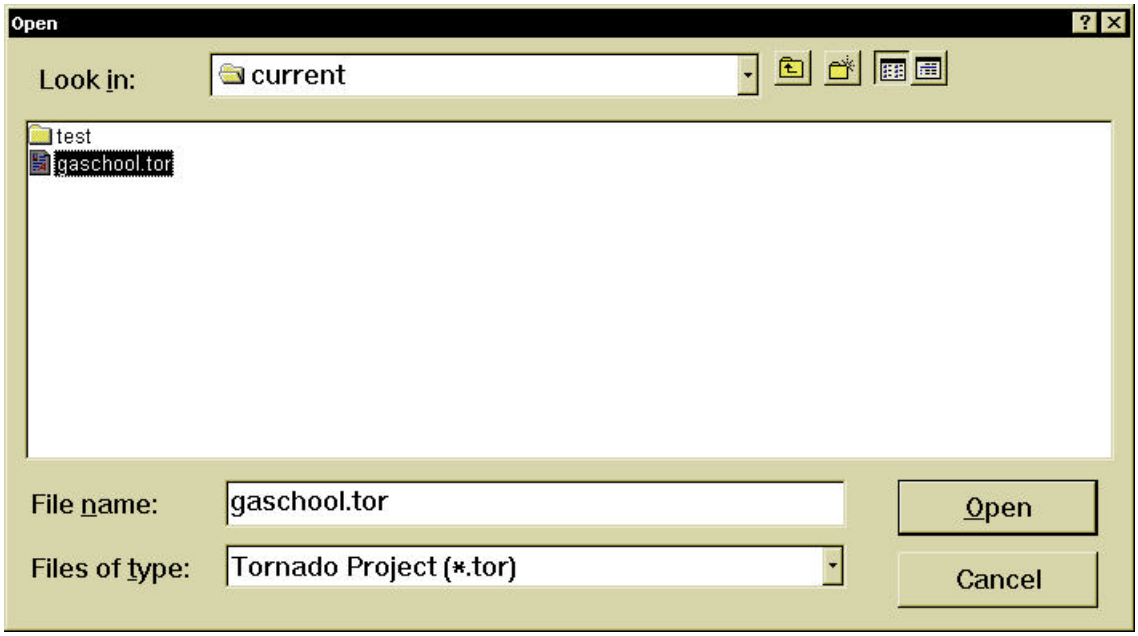
To exit the program, select the *File* menu and *Exit*. You will always be prompted to save your current project. Select *No*, since you just saved your project.

4.2 Editing an Existing Project

The second half of this tutorial covers opening existing project files and producing project reports.

4.2.1 Opening an Existing Project

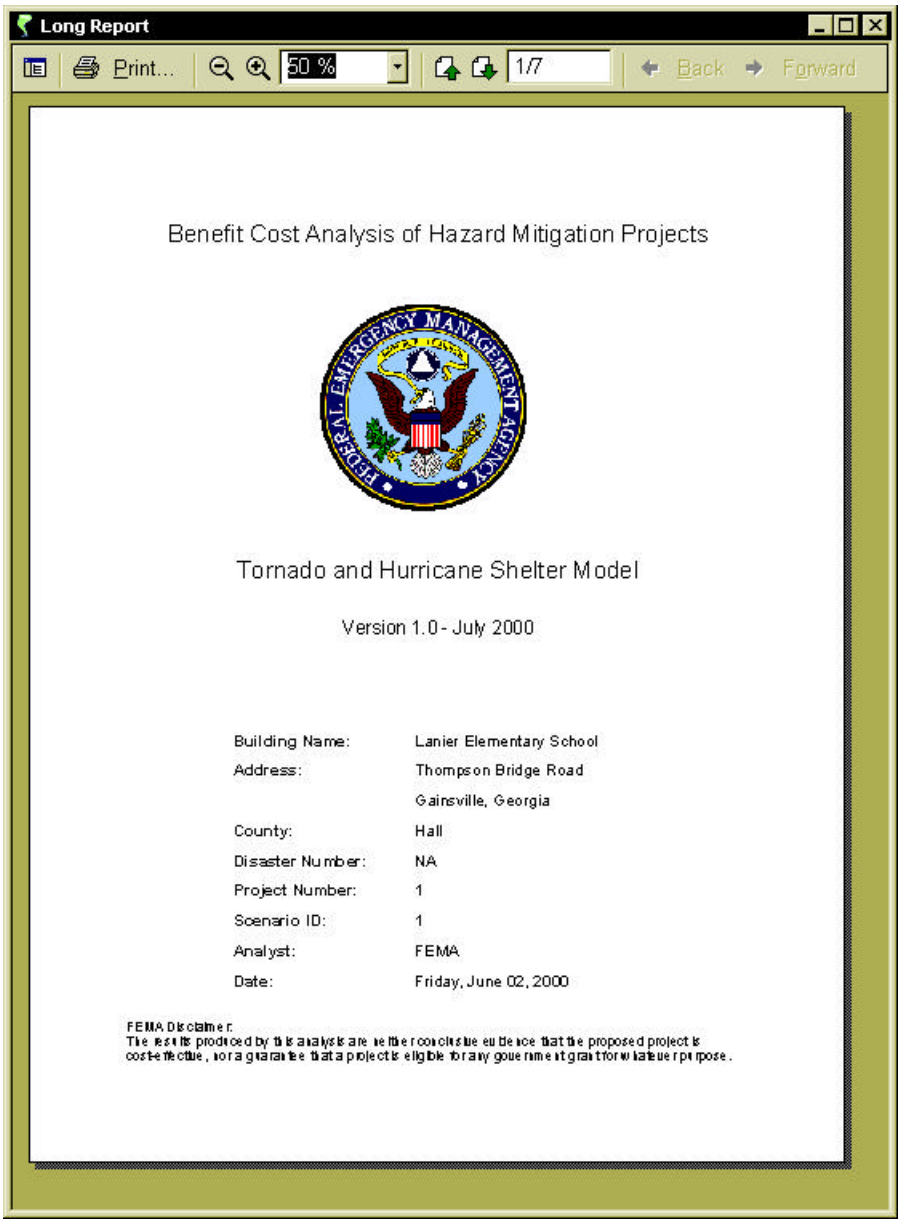
There are two ways to open an existing file. When you first start the program, you can selected the *Existing File* option. Also, if you are already in the program, you can use the *File* menu and *Open* to open an existing file. Using either method, you should have a screen like the following:



Open *gaschool.tor*, a sample project file installed with the program. You can only have one project open at a time.

4.2.2 Preview Long Report

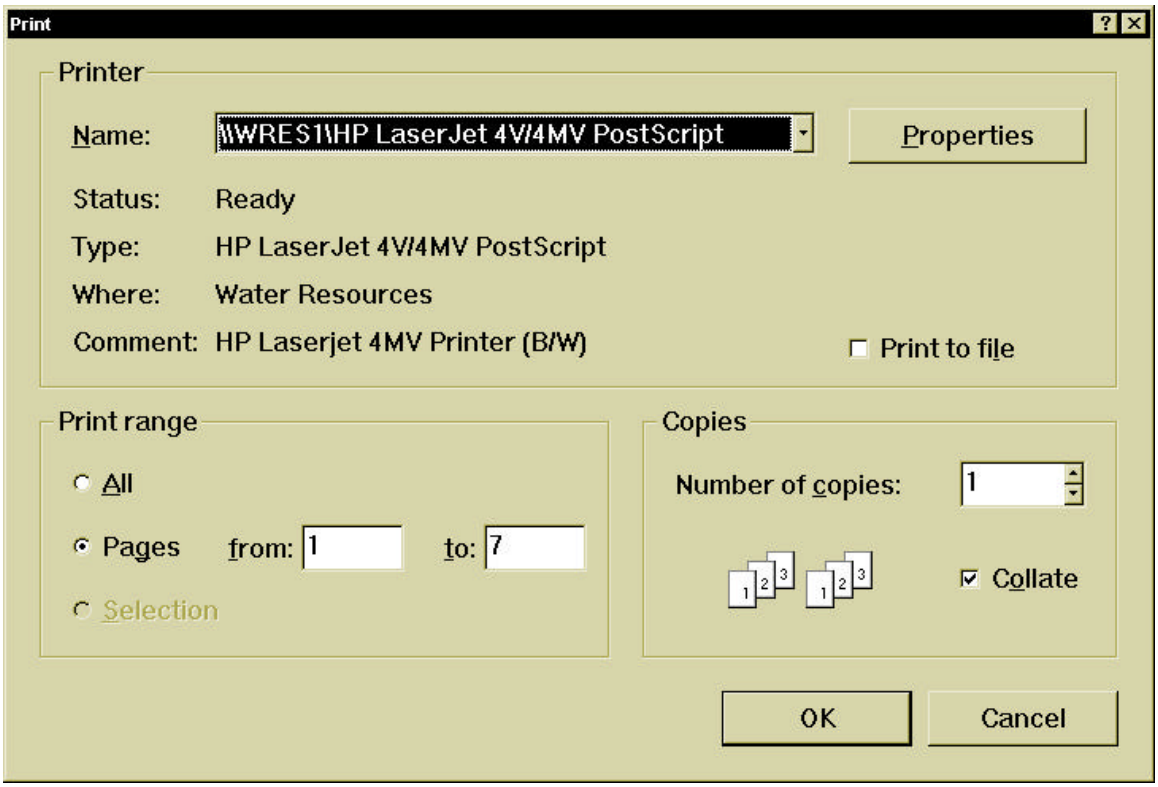
After the file has been loaded, you will notice that the *Benefit Cost Analysis* button and menu item are active. As mentioned before, this indicates that the project has sufficient information to perform a benefit costs analysis. This also indicates that *Print* and *Print Preview* in the *File* menu are active. In the *File* menu, select *Print Preview, Long Report*. The following screen will appear:



The long report is a seven-page document that gives details on the input data, hazard statistics, and benefit cost results. Pages 1 through 4 list the input data entered in the *Project Descriptive Information, Building Information, Tornado Hazard Information* and *Mitigation Project Information* screens. Page 5 shows a summary of the tornado statistics associated with the project and page 6 summarizes the extreme wind statistics. Finally, page 7 shows the benefit-cost analysis information and remarks on the options chosen by the user. These remarks DO NOT indicate that an error was made, only that the project must be carefully reviewed.

To zoom in or out on the current page, use the + and – magnifying glass icons or the drop-down box with the percent zoom. To scroll through the pages, use the up and down arrow page icons. *Back* and *Forward* become active after you have scrolled through several pages.

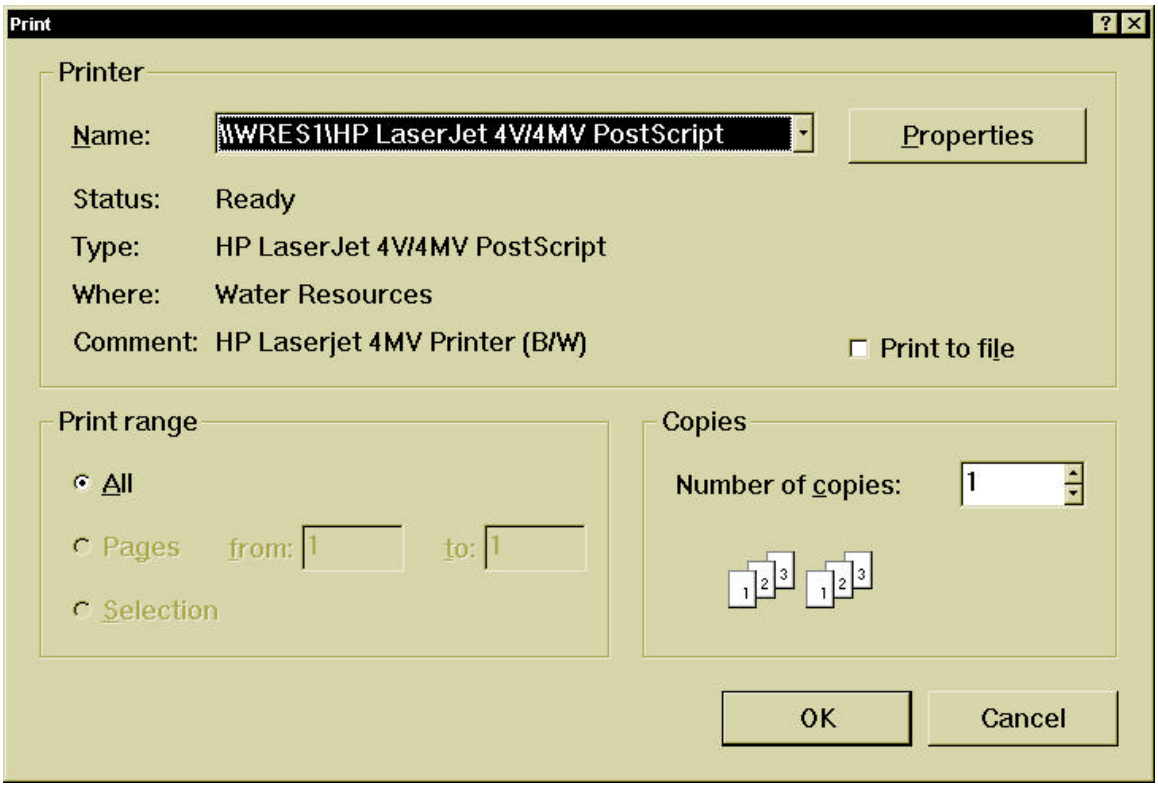
Once you have previewed the report, use the print icon to send the file to the printer. Depending on your printer, you should see a screen similar to the following:



After you click *OK* to print the report, you will be returned to the *Print Preview* screen. To exit the *Print Preview* screen, click on the icon in the upper left corner and select Close or click the X in the upper right corner of the screen.

4.2.3 Print Short Report

There are two methods to print the long and short reports. The previous section described the first method that uses *Print* in the *Print Preview* screen. To use the second method, go to the *File* menu and select *Print* and *Short Report*. You should see a screen similar to the following:



Notice that the range for pages to print is dimmed since the short report is only one page long. Click *OK* to print this report. You will then be returned to your original screen.

5 Using the Program

This chapter discusses two topics: data sources for some of the inputs required by the model and an overview of the methods and assumptions used for calculation of benefits and costs.

5.1 Data Sources

5.1.1 Project Descriptive Information

The data required for the *Project Descriptive Information* screen is mainly for project documentation.

Project Descriptive Information

Input	Data Source
Building Name	Descriptor to identify building.
Address	Project location
City	Project location
State	Project location (required)
County	Project location (required)
Disaster Number	Assigned by FEMA for declared disasters, available at FEMA's web page (www.fema.gov)
Project Number	Assigned by FEMA, state, or municipality for project management purposes
Scenario Run ID	Assigned by analyst for comparison of alternatives (optional)
Analyst	Name of person or organization performing analysis

5.1.2 Building Information

The data required for the *Building Information* screen come from design information about the proposed project.

Building Information (all fields required)

Input	Data Source
Building Longest Length	Building footprint
Building Longest Width	Building footprint
Shelter Area	Project design data; should not exceed building footprint area
Shelter Construction Type & Window Area	Project design data
Hurricane Shelter Occupancy	Project design information, should not cause less than 10 ft^2/person
Hourly Tornado Shelter Occupancy	Project design information, should not cause less than 5 ft^2/person
Time Zone	Project location, default based on selected county
Daylight Savings	Project location, default based on selected county

The building length and width should be the longest dimensions of the sides of the entire building where a shelter is located, even if the shelter is located in only part of the building (see Section 5.2.4.1.1. for more information). These dimensions define the "target area" for tornadoes. The shelter area is only that area of the building that is used during an emergency.

The shelter construction categories are:

- Reinforced & Precast Concrete
- Reinforced Masonry
- Unreinforced Masonry
- Steel
- Wood
- User-Defined

Window coverage categories are:

- Less than 7% of wall area
- Greater than 7% of wall area

Each combination of construction and window categories, with the exception of the *User-Defined* category, are associated with a corresponding pre-mitigation injury and death damage curve, which are given as defaults on the *Mitigation Project Information* screen.

Usually, hurricane occupancy can be predicted based on the maximum capacity of the shelter because hurricanes can be forecast well in advance for people to travel to the shelter. These people are assumed to remain in the shelter for the duration of the hurricane. The unpredictability of tornadoes makes it likely that the people in the building at the time the tornado occurs will be the ones to head for the shelter. Therefore, the shelter occupancy at any given time in the day is equal to the building occupancy. The occupancy input should be based on the project design of the shelter, where occupants during a hurricane should have at least 10 square feet and occupants during a tornado should have at least 5 square feet. The program automatically adjusts the average hourly occupancy value if a location observes daylight savings. For those counties that contain two time zones or different observances of daylight savings, the user should adjust the time zone and daylight savings as necessary so that the occupancy shown is representative of average conditions. In non-hurricane regions, the hurricane occupancy should always be set to zero, since the shelter will only be used against tornado hazards.

5.1.3 Tornado Hazard Information

The program has an extensive database of tornado information for each county in the U.S collected by the National Atmospheric and Oceanic Administration (NOAA). This database is used to compute tornado probability of occurrence. The user must select a set of counties to calculate the tornado statistics for the project location. A status box indicates when a sufficient number of counties has been chosen to produce meaningful tornado statistics.

The actual selection of counties depends on the scope of the project and the analyst's knowledge of tornadoes around the project location. In most cases, selecting a region within a given radius around a county will provide a sufficient tornadoes. However, for smaller states or for statewide planning purposes, the entire state of interest may be appropriate.

The *User-Selected Counties* option should only be used when the analyst has site-specific information that supports the selection of a specific group of counties. For example, tornado occurrence has been shown to depend on relief; therefore, the user may want to include in the sample only counties with similar terrain characteristics. Another situation in which manual modifications may be needed is when it is politically undesirable to include counties in neighboring states.

In any case, manual selection of counties should produce a region comprised of contiguous counties. The long report lists all of the counties in the statistical sample region broken down by state. The user or reviewer can use this list to verify the continuity of the sample region.

5.1.4 Mitigation Project Information

The data required for the *Mitigation Project Information* screen comes from mitigation project planning and analysis of potential damages in the event of a hurricane or tornado.

Mitigation Project Information (all fields required except as noted)

Input	Data Source
Mitigation Project Description	Descriptor for mitigation project (not required)
Project Cost	Capital cost of implementing the project
Maintenance Cost	Annual operating and maintenance expenses
Project Lifetime	Expected useful life of the project (usually 30 to 50 years)
Discount Rate	User-selected discount rate. Federally funded projects use 7%
Injury Cost	Monetized injury damages. The Federal Aviation Administration (FAA) uses $12,500 per major injury
Death Cost	Monetized loss-of-life damages. The FAA uses $2,200,000 per death
Design Wind Speed	From Figure 2-2 in the FEMA publication 361 *Design and Construction Guidance for Community Shelters* and on page 16 of the *Evaluation Checklists*
Injury: Pre-Mitigation	Evaluation of current building condition. Default curves are provided for given building types
Injury: Mitigation Effectiveness	Estimated protection provided by mitigation project. Default curves are provided for selected design wind speeds
Injury: Post-Mitigation	Calculated based on pre-mitigation and mitigation effectiveness
Death: Pre-Mitigation	Evaluation of current building condition. Default curves are provided for given building types
Death: Mitigation Effectiveness	Estimated protection provided by mitigation project. Default curves are provided for selected design wind speeds
Death: Post-Mitigation	Calculated based on pre-mitigation and mitigation effectiveness

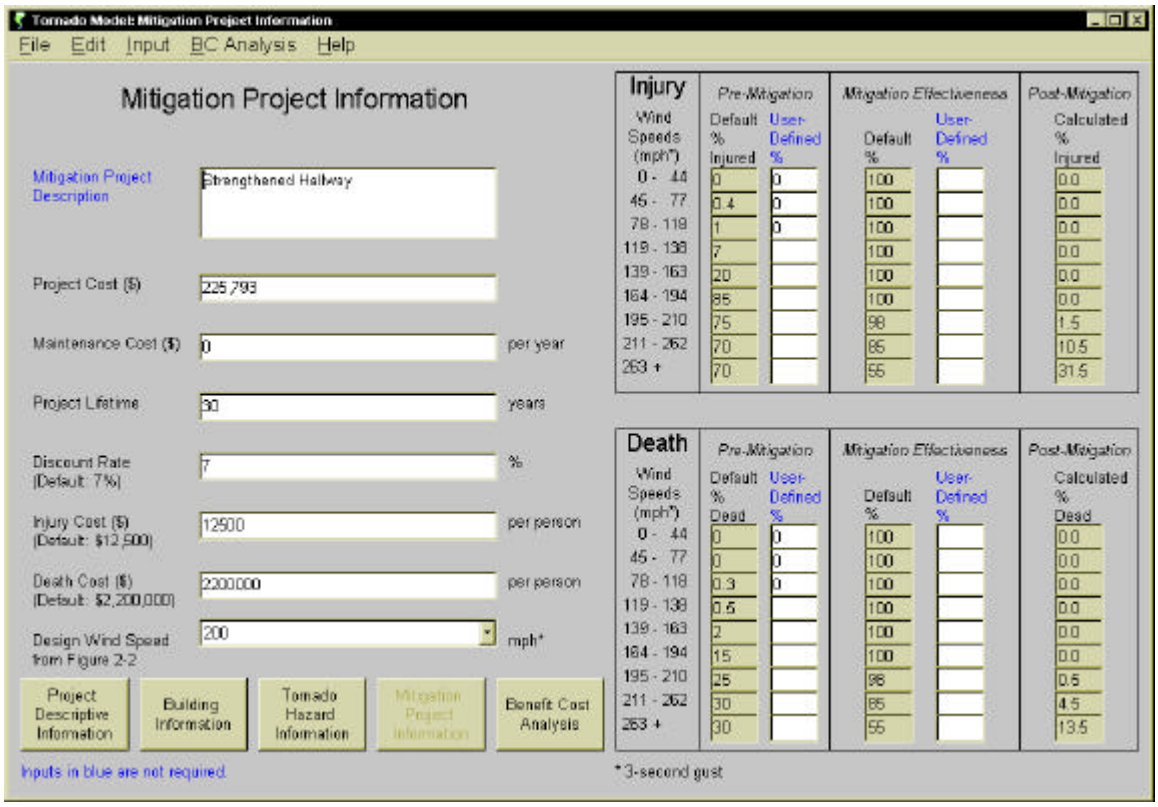
The mitigation project description provides general information about the proposed mitigation project. The project cost should include all one-time costs to implement the mitigation project, while the maintenance cost should include annual costs to insure that the project functions properly. Both cost figures should only account for additional costs to construction from implementing the mitigation project. For example, if building has been planned to withstand 150 mph winds, but a mitigation project is proposed to strengthen it to 200 mph, then the costs should only include the additional measures needed to strengthen the structure. Often the total construction cost can be prorated by a construction expert or contractor that is familiar with the additional costs for strengthening a shelter against stronger winds.

The project lifetime is the useful life of the mitigation project. The discount rate is used for present value calculations and has a default value of 7% for FEMA funded projects.

The injury and death costs assign a dollar value to human injury and death. The Federal Aviation Administration (FAA) has estimated defaults for major injury and death of $12,500 and $2,200,000, respectively.

The *Design Wind Speed* is the 3-second gust wind in miles per hour (mph) that the FEMA publication 361 *Design and Construction Guidance for Community Shelters* recommends for shelters. Figure 2-2 in this publication provides the geographic distribution of these values. This map is also on page 16 of the *Evaluation Checklists* file that was installed with the model (see Section 2.2 for the location of this file).

The last set of information estimates percent injury and death associated with structural failure at different wind speed ranges. The pre-mitigation values have defaults based on the construction type and window coverage selected on the *Building Information* screen. These default values for pre-mitigation must be adjusted to account for local building codes and standards and the current condition of the building. Most communities require structures to be built, at a minimum, to withstand certain wind levels. The pre-mitigation default values do not consider these standards, since they vary through the country, and the user must enter values consistent with these standards. For example, a shelter may have been designed based on a local minimum design wind speed of 100 mph. In the *User-Defined Pre-Mitigation* columns for injury and death, zeroes should be entered for all wind ranges up to and including 100 mph, as shown in the figure below.



Similarly, the mitigation effectiveness values should be adjusted if the default mitigation effectiveness does not fully reflect the actual mitigation design.

Supporting documentation must accompany any analysis that requires these kinds of adjustments.

The model is intended to analyze the economic feasibility of retrofitting an existing building to install a shelter capable of withstanding high winds. This includes adding a shelter to an existing building. However, the software can also be used to evaluate cost-effectiveness of constructing a new building, where the entire building will be used as a shelter. In this case, the user needs to select the *User-Defined* option in the *Shelter Construction Type* dropdown box in the *Building Information* screen and supply the damage and mitigation effectiveness curves in the *Mitigation Project Information* screen. The loss data must accurately reflect the injuries and deaths expected in the population expected to use the shelter. These deaths and injuries must be computed based on the locations where the targeted population is anticipated to be when the wind event occurs, if the shelter is not constructed. The development of these data is not a trivial task and requires careful examination of site conditions and consultation with wind engineers, community planners, and emergency response professionals.

5.2 Calculation Methods and Assumptions

The methodology used in this software application was based upon available tornado and wind data and assumptions described in the following sections.

5.2.1 Building Information

Exposure to tornadoes depends on the size of the building and the frequency and severity of tornado events. As shown in the next section, in the worst-case scenario, a tornado has the greatest chance of striking a building if it approaches the structure perpendicular to its longest dimension. The model assumes that this dimension can be approximated as the diagonal resulting from the longest width and length.

Tornado occurrence varies with the time of day and geographic location. Therefore, the software calculates hourly tornado probabilities for the statistical sample region. It is assumed that during a tornado emergency the shelter houses all of the people in the building at that time.

The shelter area corresponds to that portion of the building that will serve as protection during a tornado or hurricane. Typically, this area is smaller than the entire building footprint. It is assumed that tornado emergencies will have relatively short shelter occupancy times and that 5 ft^2 per person is an acceptable minimum space requirement. Hurricanes demand longer occupancy times and the minimum requirement increases to 10 ft^2 per person. The user should account for additional factors such as wheelchairs and life support equipment, if needed.

5.2.2 Tornado Hazard Information

The county-based statistics use the tornado database compiled in the NOAA Storm Prediction Center archives and available at www.spc.noaa.gov/archive/tornadoes. The statistics are based on tornado events that have a recorded length, width, tornado Fujita scale (F-scale), and time of occurrence. When the user selects a group of counties, the tornado events are accumulated for the selected counties to determine if there is sufficient data available for tornado statistics.

5.2.3 Mitigation Project Information

The default pre-mitigation injury and death damage curves are based on the construction and window categories selected in the *Building Information* screen and shown in the following tables for nine wind speed ranges. The wind ranges roughly correspond to specific tornado Fujita scale (FS) and hurricane Saffir-Simpson Scale (SSS), as shown in the FS / SSS column. After structural collapse, the percent injuries and deaths total 100%.

Pre-Mitigation Damage Curves:

Expected percent death (D) and injury (I) to occupants of buildings with window coverage greater than 7% of wall area

WIND PARAMETERS			*BUILDING CONSTRUCTION CATEGORY*									
			D	***I***	***D***	***I***	***D***	***I***	***D***	***I***	***D***	***I***
Wind Range	Wind Speed (mph, 3-sec. gust)	FS / SSS	Reinforced Precast Concrete		Reinforced Masonry		Un-reinforced Masonry		Steel		Wood	
1	0 – 40		0	0	0	0	0	0	0	0	0	0
2	45 - 77	F0	0	0.6	0	0.6	0	1	0	1	0	1
3	78 - 118	F1 / C1	0.3	2	0.3	2	0.3	3	0.3	5	1	7
4	119 - 138	F2 / C2	1	10	2	15	15	85	2	10	10	90
5	139 - 163	F2 / C3	3	30	15	85	25	75	5	45	20	80
6	164 - 194	F3 / C4	15	85	25	75	30	70	25	75	25	75
7	195 - 210	F3 / C5	25	75	30	70	30	70	25	75	25	75
8	211 - 262	F4	30	70	30	70	30	70	25	75	25	75
9	263 +	F5	30	70	30	70	30	70	25	75	25	75

Values are % of total occupancy

	building envelope intact	D + I = 0%
	building envelope breached/ no structural collapse	D + I = 50% (most cases)
	structural collapse	D + I = 100% (all cases)

Pre-Mitigation Damage Curves:

Expected percent death (D) and injury (I) to occupants of buildings with window coverage equal to or less than 7% of wall area

WIND PARAMETERS			*BUILDING CONSTRUCTION CATEGORY*									
			D	***I***	***D***	***I***	***D***	***I***	***D***	***I***	***D***	***I***
Wind Range	Wind Speed (mph, 3-sec. gust)	FS / SSS	Reinforced Precast Concrete		Reinforced Masonry		Un-reinforced Masonry		Steel		Wood	
1	0 – 40		0	0	0	0	0	0	0	0	0	0
2	45 - 77	F0	0	0.4	0	0.4	0	0.6	0	0.6	0	0.6
3	78 - 118	F1 / C1	0.3	1	0.3	1	0.3	2	0.3	3	0.7	4
4	119 - 138	F2 / C2	0.5	7	1	10	15	85	1	7	10	90
5	139 - 163	F2 / C3	2	20	15	85	25	75	3	30	20	80
6	164 - 194	F3 / C4	15	85	25	75	30	70	25	75	25	75
7	195 - 210	F3 / C5	25	75	30	70	30	70	25	75	25	75
8	211 - 262	F4	30	70	30	70	30	70	25	75	25	75
9	263 +	F5	30	70	30	70	30	70	25	75	25	75

Values are % of total shelter occupancy

	building envelope intact	D + I = 0%
	building envelope breached/ no structural collapse	D + I = 50% (most cases)
	structural collapse	D + I = 100% (all cases)

The pre-mitigation injury and death default values must be adjusted to account for the actual condition of the building being retrofitted. Design information or engineering inspection results must be used to determine the maximum wind speed that the building can withstand without causing any injuries and deaths. Once this threshold has been determined, all of the default values must be replaced with zeroes in the *User-Defined %*column of the *Mitigation Project Information Screen* to reflect the fact that no damage is expected for speeds less than this threshold. Unrealistically high benefit-cost ratios will result if the user fails to take this fact into account.

For post-mitigation conditions, the default mitigation effectiveness values are based on the selected mitigation design wind speed. These values are the same for injuries and deaths.

The following table shows the default values

Mitigation Effectiveness:

Expected Reduction of Percentage Death and Injury to Occupants of Shelters

WIND PARAMETERS			*DESIGN WIND SPEED (MPH)*			
Wind Range	Wind Speed (mph, 3-sec. gust)	FS / SSS	130 (mph)	160 (mph)	200 (mph)	250 (mph)
1	0 – 40		100	100	100	100
2	45 - 77	F0	100	100	100	100
3	78 - 118	F1 / C1	100	100	100	100
4	119 - 138	F2 / C2	98	100	100	100
5	139 - 163	F2 / C3	85	98	100	100
6	164 - 194	F3 / C4	55	85	100	100
7	195 - 210	F3 / C5	20	55	98	100
8	211 - 262	F4	0	20	85	98
9	263 +	F5	0	0	55	85

building envelope intact

building envelope breached/ no structural collapse

structural collapse

6 Benefit-Cost Analysis

Benefits are calculated as damages avoided because of construction of the shelter. Benefits stem from avoided deaths and injuries, monetized according to the dollar value of loss of life and injury used by the FAA. Benefits are computed separately for tornado and hurricane hazards. Cost calculations are based on project cost information. This chapter describes the equations and assumptions used in these calculations.

Project benefits only reflect avoided shelter injuries and deaths due to the mitigation project. Therefore, all benefits are highly dependent on the building occupancy values and increase in structural resistance. Both tornado and hurricane benefits are calculated by determining the difference between pre-mitigation deaths and injuries and post-mitigation deaths and injuries. A general equation for the number of deaths of injuries for a given instance (pre- or post-mitigation) is:

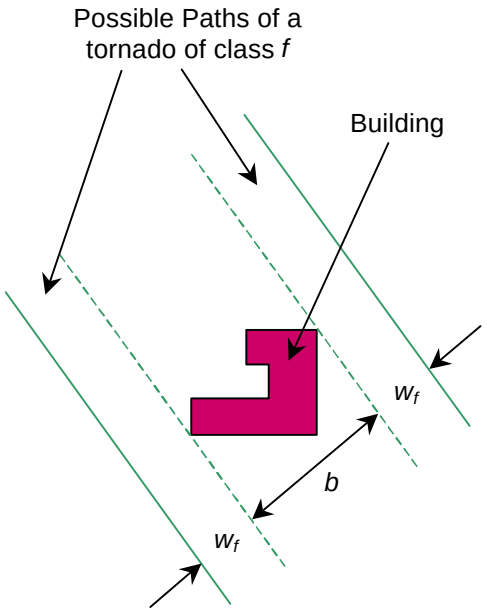
$$\textit{Number of deaths or injuries} = \textit{Occupancy} \times \textit{Probability(death or injury)} \times \textit{Probability(Event)}$$

where *Occupancy* is entered on the *Building Information* screen for hurricane and tornado, *Probability(death or injury)* is computed from on the tables on the *Project Mitigation Information* screen, and *Probability(Event)* is based on the probability of a tornado or hurricane event of given severity, which is measured using the Fujita scale for tornadoes and the wind speed distribution for hurricanes.

The numbers of deaths or injuries are converted to dollars using FAA values for loss of life and injuries.

6.1 Tornado Benefits

Tornado hazards have been summarized on a county basis based on data from the NOAA Storm Prediction Center archives. The tornado hazard calculation determines the impact of a given Fujita class tornado AT a given hour, *e.g.*, what is the probability of a F3 tornado hitting the building at 9 am EST? To determine this probability, the potential hazard area for a building of given dimensions is first computed. This calculation is explained using the diagram shown below.



In the figure, b is the maximum building dimension that can face the tornado and w_f is the potential path width for a tornado of class f that strikes the building normal to its broadest dimension.

A tornado of class f will impact a building if its path falls anywhere between the solid lines. It is assumed that the building suffers the same damage regardless of where in the footprint the tornado hits. Therefore, the exposure area a_f for the building will be equal to

$$a_f = l_f (2w_f + b)$$

where l_f is the path length for a tornado of Fujita class f. The average annual potential hazard area for the building caused by tornadoes of class f is equal to

$$\bar{a}_f = \frac{1}{N}\sum_{i=1}^{n}(2l_f^i w_f^i + bl_f^i) = 2\bar{w}_f \bar{l}_f + b\bar{l}_f$$

Defining

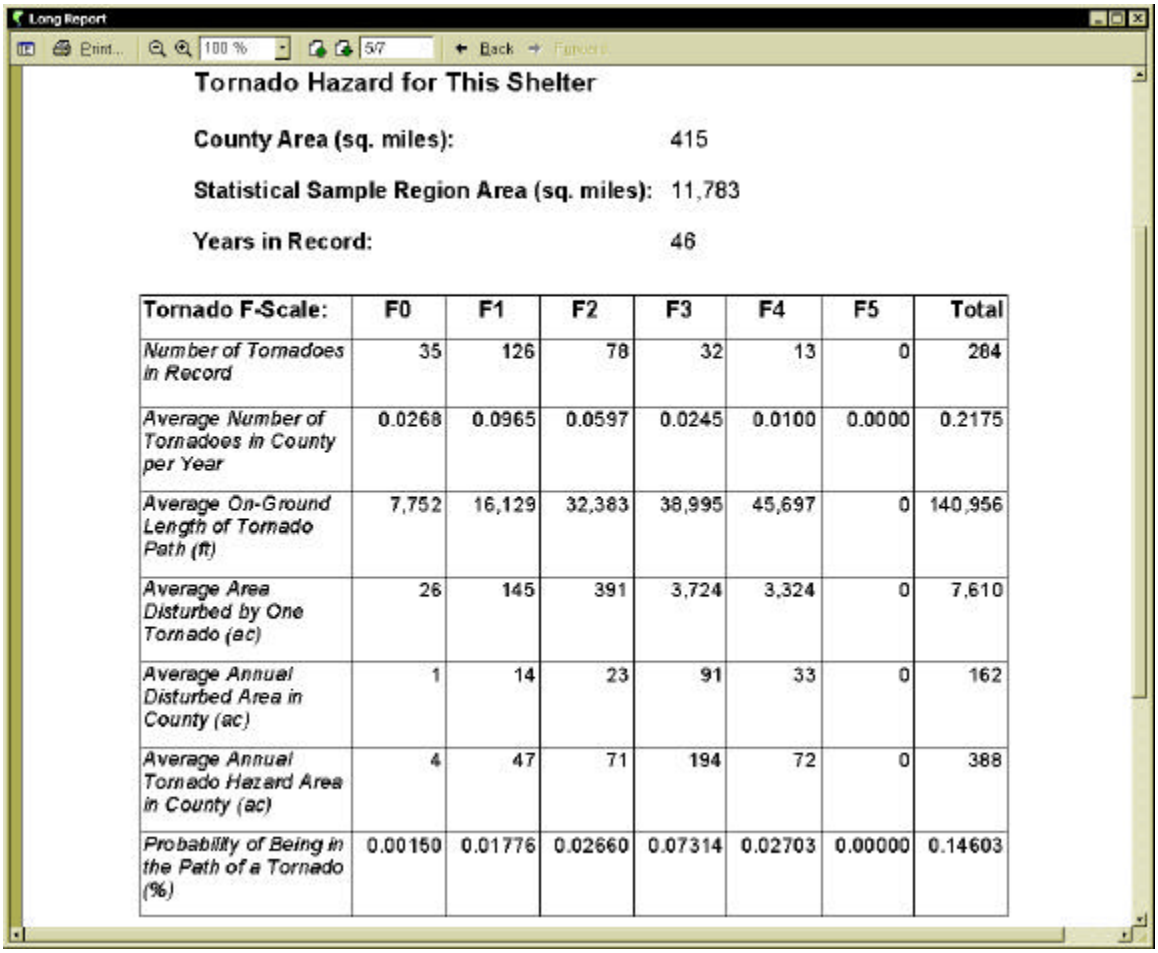
$$\bar{A}_f = \bar{w}_f \bar{l}_f$$

the result is

$$\bar{a}_f = 2\bar{A}_f + b\bar{l}_f$$

where $\bar{a}_f$ is the average annual potential hazard area, $\bar{A}_f$ is the average annual disturbed area, and $\bar{l}_f$ is the average annual path length for tornadoes of class *f*. The superscript *i* indicates a class *f* tornado occurrence; *n* is the total number of class *f* tornadoes in the record and *N* is the number of years in the record. This calculation requires statistics of tornado width and length and must be performed for each tornado class.

The probability of a building being hit by a tornado of given class is calculated as the ratio of the average annual potential hazard area to the total area of the sample region. The Long Report shows a summary of these calculations.



Tornado Hazard for This Shelter

County Area (sq. miles): 415

Statistical Sample Region Area (sq. miles): 11,783

Years in Record: 46

Tornado F-Scale:	F0	F1	F2	F3	F4	F5	Total
Number of Tornadoes in Record	35	126	78	32	13	0	284
Average Number of Tornadoes in County per Year	0.0268	0.0965	0.0597	0.0245	0.0100	0.0000	0.2175
Average On-Ground Length of Tornado Path (ft)	7,752	16,129	32,383	38,995	45,697	0	140,956
Average Area Disturbed by One Tornado (ac)	26	145	391	3,724	3,324	0	7,610
Average Annual Disturbed Area in County (ac)	1	14	23	91	33	0	162
Average Annual Tornado Hazard Area in County (ac)	4	47	71	194	72	0	388
Probability of Being in the Path of a Tornado (%)	0.00150	0.01776	0.02660	0.07314	0.02703	0.00000	0.14603

To account for hourly variations, for each tornado class the hourly distribution of occurrences is determined, which involves counting all tornadoes of a given class that occurred at a particular hour and dividing by the total number of events in the record for that tornado class. The probability of a given class *f* tornado occurring at a given hour is computed by multiplying the hourly probability for that class (which sums to 100% for an entire day) times the probability of that class occurring for an entire year.

Once these probabilities are known, the expected annual number of deaths caused by a tornado of class *f* can be computed by multiplying the deaths that

this tornado is likely to cause times its probability of occurrence. A similar computation is performed for injuries. The deaths and injuries that a given tornado may cause are related to the pre-mitigation condition of the building. The average number of deaths and injuries can be monetized by multiplying those figures times the FAA values for loss of life and injury.

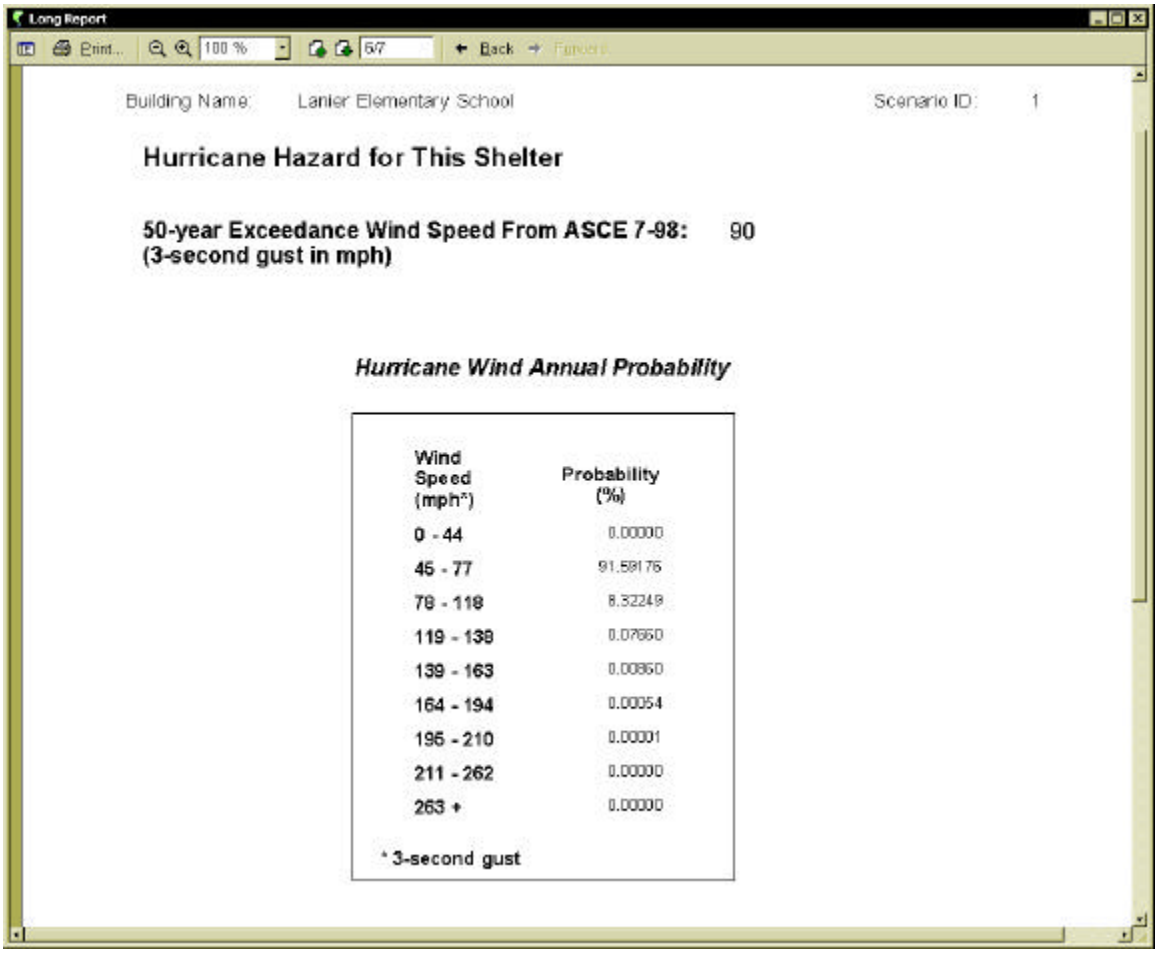
This procedure is repeated for all tornado classes and the results added to obtain the total expected annual dollar value of death and injury caused by tornadoes of all classes. The entire calculation is done once more using post-mitigation conditions. The difference between these two sets of values gives the annual benefits associated with the mitigation project.

6.2 Hurricane Benefits

Hurricane hazards have been determined for the U.S., since researchers have established extreme wind exceedance probability information throughout the country, which includes hurricane wind data. In ASCE 7-98, *Minimum Design Loads for Buildings and Other Structures*, the 50-year exceedance wind speed (in mph for 3-second gusts) is given for the U.S. and territories. This publication also contains adjustment factors to this 50-year exceedance wind speed to obtain the speeds for 5-, 10-, 25-, 100-, 200-, and 500-year mean recurrence intervals (MRI).

To determine the hurricane hazard at a given location, a database of maximum 50-year wind speed for each county was developed from the ASCE 7-98 wind maps. Next, adjustment factors for different mean recurrence intervals were fit to log regression curves to estimate the exceedance probability for any given wind speed. When the user selects a county, the probability of each of the nine wind speed intervals is determined by subtracting the exceedance probabilities for the two wind speeds that bound that interval.

The Long Report shown in the following figure displays these probabilities for each wind speed range.


Long Report

Print... 100 % 6/7 Back Forward

Building Name: Lanier Elementary School Scenario ID: 1

Hurricane Hazard for This Shelter

50-year Exceedance Wind Speed From ASCE 7-98: 90
(3-second gust in mph)

Hurricane Wind Annual Probability

Wind Speed (mph*)	Probability (%)
0 - 44	0.00000
45 - 77	91.59176
78 - 118	8.32249
119 - 138	0.07660
139 - 163	0.00860
164 - 194	0.00054
195 - 210	0.00001
211 - 262	0.00000
263 +	0.00000

* 3-second gust

For maximum MRI wind speeds, the lowest wind speed range probability will often be 0.0, since the exceedance probability of both the lower and upper bound of that wind range is equal to 1.0. This implies that this location will always have maximum wind speeds greater than this range.

Because the pre-mitigation damage curves relate wind speed to numbers of deaths and injuries, the wind speed exceedance probability can be used to determine the probability distribution of deaths and injuries. Using the FAA values for loss of life and injury, this distribution can be transformed into the probability distribution for damages in dollars. The area under this curve is equal to the expected annual damages.

This calculation is repeated using the damage curves for post-mitigation conditions. The difference between the annual expected damages before and after mitigation is equal to the benefits.

6.3 Project Costs

To compare costs and benefits on an equivalent basis, all project costs must be converted into equivalent annual costs. This is accomplished by using a standard economic equation that distributes a one-time cost over the project lifetime based on the discount rate. When this annualized cost is added to the maintenance costs, an estimate of the annual costs of the project can be calculated.

6.4 Benefit-Cost Ratio

With the cost and the benefits known, the two measures of cost-effectiveness can be calculated. The expected annual net benefits are the difference between the benefits and the costs, where a positive value indicates a cost-effective project. The Benefit-Cost Ratio is calculated by dividing the annual benefits by the annual costs, where a value greater than or equal to one indicates a cost-effective project.