Appendix B – Detailed Techniques for a Hazard Analysis

This appendix deals mainly with advanced techniques of analyzing different hazards. Some of the suggested techniques are new and are mere suggestions for how your plan might deal with evaluating specific hazards in its risk and vulnerability assessments. Much of this information is aimed at planners and analysts who are already familiar with quantitative research methods and basic concepts of probability theory. This appendix is not intended as a starting point for research. Rather, it tries to summarize best known standards and practices (short of detailed engineering studies) that communities can use to enhance their hazard analysis abilities and improve their hazard mitigation plans. **For introductory information on known hazards in Michigan, please refer to EMD-PUB 103 Michigan Hazard Analysis.** For more general information about starting a hazard analysis and mitigation plan, please go back to read the introductory materials and early sections in this workbook (steps 1a through 1d).

This appendix contains two sections. The first gives detailed advice on techniques for calculating risks and expected annual costs/damages from different hazards. (Not all hazards have established and objective techniques for evaluation, but this section will address the sort of techniques that could be used, while more detailed methods are being developed by researchers.) The second section provides much information from FEMA guidance materials that can be used to further estimate disaster costs. Instead of focusing on techniques for a hazard, the second section will describe general methods of quantifying the costs of utility interruption, emergency response, evacuations and displacement, et cetera.

Section 1—Methods to Quantify Risks and Expected Costs From Each Hazard

This appendix will provide detailed techniques and information that can be used by communities to analyze each hazard that they consider significant. The techniques suggested here are intended to be compatible with the sort of Benefit-Cost Analysis that FEMA uses to assess projects. Benefit-Cost Analysis contains many subjective elements, but can be helpful to allow community stakeholders to discuss and weigh the different types of hazard impacts, when deciding what sort of mitigation actions are worth taking. As mentioned in the Risk Assessment section of this workbook, these techniques are intended to suggest means by which communities can perform an advanced-level analysis of top-priority hazards. If some of these methods seem too demanding or inappropriate for your hazard analysis, others can be used instead—as long as they provide some way to establish mitigation priorities and determine what vulnerabilities are worth addressing by mitigation activities in your community.

This appendix builds on the information given earlier in this workbook, in the section on Risk and Vulnerability Assessments. In that section, three different levels of risk assessment were described. These were:

1. A cursory assessment in which the hazard's possible effects are briefly described—usually just to explain why it is not considered a significant hazard in the community.

2. A standard analysis in which it is attempted to accurately and validly describe risks and vulnerabilities from a community's significant hazards, even though the community may have limited data, expertise, resources, and time to devote to the analysis. Most communities have at least 3-7 significant hazards.

3. An advanced analysis in which the community wishes to use "best practices" to analyze its top hazards, and has fairly good information, expertise, resources, and time to use in the analysis. Usually, this sort of time and effort is only worth expending on hazards that are likely to pose a large amount of risk or distress to the community. Whenever possible, top hazards should be given an advanced analysis.

Methods of Advanced Risk Assessment

As mentioned previously, the Risk and Vulnerability Assessments involve estimating the *probability* of harm and also the *severity* of harm from each hazard that is possible in your community. Hazards that are considered insignificant can be addressed with merely a cursory analysis in your local plan. Hazards that have the real potential to cause disruption, damage, harm, or loss of life should be considered significant, and should be described more fully in your plan. The degree of risk should be estimated for significant hazards. There are different ways to measure risk, but available measures can be adjusted to allow them to be compared to each other. For example, many different types of impacts can be represented with a dollar value. FEMA assesses mitigation projects by comparing the cost of the mitigation project with the costs of continuing to endure damages from the hazards being addressed. (This process generally falls under the name "benefit-cost analysis" and can be an excellent tool to help a community identify, compare, and think about the potential effects of the hazards they face.) Detailed information on measuring harm in dollar values was obtained from various FEMA guidance documents and is summarized in this section. This appendix is meant to supplement the sections on Risk and Vulnerability Assessment by providing instruction, ideas, and suggestions for those who wish to use more advanced techniques of hazard analysis. (Although definitions often vary, in this workbook the Risk Assessment will focus on probabilities and the Vulnerability Assessment will focus on calculating damages and priorities. This appendix clearly relates to both steps of a detailed hazard analysis.)

EXAMPLE OF DETAILED RISK ESTIMATION

NOTE: THIS SORT OF ESTIMATE IS EXTREMELY USEFUL AND IS RECOMMENDED FOR EACH SIGNIFICANT HAZARD AFFECTING A COMMUNITY. THE AMOUNT OF DETAIL AND EFFORT THAT GOES INTO THESE ESTIMATES SHOULD BE GENERALLY PROPORTIONAL TO THE AMOUNT OF RISK POSED BY A HAZARD. IF AN INITIAL EXAMINATION SUGGESTS SIGNIFICANT RISK, MORE INVESTIGATION SHOULD BE DONE. IF CONTINUED INVESTIGATION CONFIRMS EXTENSIVE RISKS, IT IS WELL WORTH GOING INTO DETAIL ABOUT THE NATURE OF THESE RISKS, USING A METHOD SUCH AS THE ONE DESCRIBED IN THIS EXAMPLE.

Each type of damage that might occur in your community can be given a particular likelihood of occurring. A knowledge of probability will be very helpful in estimating risk. For example, the odds of a plane crash or hazardous materials transportation incident can be researched on the internet, but these odds will need to be translated to something pertinent for your county. For example, if plane crash odds are measured according to the number of take-offs or landings, you might get an estimate of the number of these occurring at your local airport. If the risk is merely from flights going over your county (crashes are less likely to occur from these than they are from takeoffs and landings) then you might estimate the number of flights going over the county, the chance of a crash per mile of air flight, or odds of flights going over different areas of your county. The odds of a crash should be adjusted for the odds of that crash impacting upon your county's population and developed areas.

Different scenarios could be based on the percentage of the county that contains different densities of development. A plane that crashes into a building is a more serious threat than one that crashes into a field, by threatening more lives and damaging more property in its crash area. It would be helpful to estimate what percentage of the county contains developed lands that might be affected by a plane crash. Mathematical probability theory allows all the odds of such scenarios to be <u>summarized</u> using an estimate of annual "expected" losses from a hazard. The two basic principles of probability that will be used here are (1) conditional probability, which allows us to estimate the odds of particular combinations of events, and (2) the concept of an "expected value" of damages from a hazard, based on multiplying the odds of an event by the costs of an event.

The concept of conditional probability allows us to consider many different scenarios (possible disaster or emergency events from a hazard) and estimate how likely each of those scenarios might be. Once we have considered them in a way that allows us to estimate the damages they would entail, the concept of an expected value allows analysts to combine damages with probabilities (by multiplying their values together) and estimate how much a particular disaster scenario can be expected to cost the community in a standard time period such as a year. Analysts can then add together the annual expected damages from each hazard scenario, and estimate total annual damages from each significant hazard. These expected damages can then be used to compare hazards with each other, establish hazard mitigation priorities, and justify the expense of hazard mitigation projects.

The following example demonstrates how all these concepts fit together in a hazard analysis. Different scenarios of plane crash events are presented, and each has a particular probability of occurring. Damages are estimated for each scenario, and adjusted by the probability of their occurrence. Then, expected damages for each scenario are totaled, to provide an overall summary of plane crash hazards in a community. (See the section on Transportation Accidents later in this appendix.)

ILLUSTRATIVE EXAMPLE

Let's say that you are analyzing a county and have calculated a 0.1% probability of a plane crash per year in that county, perhaps based on a historical assessment of the safety records of the planes and companies originating from a nearby airport. A survey of typical flight paths, and the land uses beneath them, might then suggest that each potential crash has only a 4% chance of affecting an inhabited or developed area of land in your county, because 96% of the at-risk areas are undeveloped. Of those areas that are developed, you estimate that 80% of them are residential areas of moderate density, for which a plane crash would likely cause about $300,000. The other 20% of the inhabited areas can be considered high-density urban development (an event there would be your county's "worst-case scenario"), in which a plane crash would probably cause about $3,500,000 in damage.

The probabilities for each scenario can be found using multiplication. The individual questions are quite simple. (1) What is the chance of a plane crash in our county in a given year? (2) What is the chance of crash affecting a populated area? (3) What are the odds of a populated area being high-density and thus turning into a kind of worst-case scenario? From the answers to these questions, specific scenarios are created. Questions 2 and 3 only matter if a plane crash has actually occurs—that is, if the condition of question 1 has been met. If the odds of a plane crashing are only .001 per year, then 99.9% of the time, nothing will happen and the county's costs will be zero. If a crash does occur, we will want to consider questions 2 and 3 about whether it will hit a populated area (4% chance), and whether that will be in the suburbs (80% chance) or in the downtown or other critical area(20% chance). That is where the concept of "conditional probability" comes in. Walk through each combination of events and multiply the probabilities as each new assumption might modify the latest. The first question produces two possibilities: a plane either crashes (.001 chance per year) or doesn't crash (.999 chance per year). **IF** a plane crashes, it either hits an inhabited area (.04 chance) or it doesn't (.96 chance). So far, the odds of a huge disaster are .001 (a plane crashes) times .04 (in an inhabited area), or .00004 per year. To go the extra step, the odds of a worst-case scenario (hitting a densely developed area) are .2 times that value, since dense urban areas are 20% of our county's developed areas and we are already assuming in such a scenario that the first two conditions of a disaster have been met (a plane crashing in an inhabited area). The odds of a worst case scenario are thus .2 times .00004, or .000008.

Damage estimates could come from housing values, emergency management response costs, business losses, or any of several other categories that FEMA recognizes as legitimate (the second section of this appendix will describe them). Each scenario should have some rough estimate of damages and costs. The probability of that scenario will then be used to put those costs in perspective. The odds of something happening, multiplied by the costs of it happening, produces a measure called "expected costs" that can help to summarize all the potential effects of a hazard, and weigh them against the costs of other hazards or the costs of taking action to mitigate such costs and damages.

Here, then, is an example of this sort of analysis when applied to a fictional plane crash scenario. A table follows these descriptions to help present the plane crash scenario risks and how they add together to produce an estimate of total plane crash risk.

1. Each year the county has a 99.9% chance of no damages from plane crash: This probability .999, times $0 costs and damages from that scenario, equals zero expected costs from that scenario in each year.
2. If the unlikely happens and a plane crashes (0.1% chance), most of these crashes (96%) will be in an uninhabited area and will result only in the costs your community requires to respond to the event. If those costs are estimated at $25,000, then the expected costs from this combination of events is .001 times .96 times $25,000, resulting in "expected" costs of $24 per year.
3. If a plane hits a moderately developed area (80% of the 4% that is inhabited) and does $300,000 in damage, the result is .001 (odds of plane crash) times .04 (odds of hitting inhabited area) times .8 (the percentage of inhabited areas that are less densely developed, such as with a road or single house) times $300,000 (damages from such a crash), plus estimated response costs of $45,000, resulting in "expected" costs of $11.04 per year from this combination of events.
4. (Worst case scenario) A plane hitting one of the worst spots of a downtown area in a crash event (in this case assumed to be merely a small town) and doing an estimated $3,500,000 worth of damage. The odds estimated for this event were .001 (odds of any plane crash) times .04 (percent of inhabited land area under flight paths or in potential crash areas) times .2 (percentage of inhabited areas that are densely developed or critical for the community) times $3,500,000 likely damage amount from such a

crash. The "expected" costs per year (including $100,000 response costs) from such a "worst-case scenario" thus is calculated as $28.80 per year.

5. Total the "expected annual costs" from all possible scenarios (listed above) to determine the total expected costs from this type of hazard (plane crash). $0 + $24 + $9.60 + $28 = $63.84

This sort of calculation can help you decide the degree of threat to your community from this hazard. At an expected annual cost of only $63.84, the airplane crash hazard appears quite low in this community. It would be difficult for the community to justify spending even a few thousand dollars on a mitigation project for this hazard, given this calculation. However, keen readers will note that this model so far only considers property damage and response costs. There may be additional harm from hazards, such as economic impact, lost services, infrastructure failure, environmental harm, or loss of life, that makes a hazard much costlier than the mere property damage that results. Additional detail can be put into this phase of the analysis. For example, there may be different types of "worst case scenarios" such as a plane destroying an important bridge or a power station. Those familiar with probability theory will recognize that it is often unnecessary to include different calculations detailing every possible combination of events, because when the math is done, the expected costs are not likely to differ very much from such calculations. The important thing for this analysis is to come up with a rough idea of how an event's likelihood works with the range of damages connected with it, to produce an overall level of risk to the community—one that is generally measurable and can be compared with the risk level of other hazards and the costs of implementing a mitigation project.

An important issue here involves the "costs" of human casualties. This may be estimated in terms of medical bills in the case of injuries, loss of income (or production potential of a person) in the case of loss of life, or the use of average insurance payouts that can be used to indicate the value of such losses. Supposing that a figure of $2.71 million (a figure taken from FEMA guidance materials) is used to represent the cost of each life lost from a plane crash event, the figures above may be increased markedly by including the costs from losses of life. (NOTE: this example has included only lives lost <u>within</u> the community, since if a community's mitigation actions are funded locally, residents may be reluctant to pay for the costs to planes and passengers from other communities. Communities that <u>contain</u> airports may wish to estimate greater costs from loss of life, such as including casualties from their flights even if accidents occur outside their community. Federally funded mitigation activities consider "social net benefits," which means that no distinction is made about where, who, or what is harmed; all damages within the United States are considered to be valid costs when calculating risks and vulnerabilities.)

Using the categories listed above:

1. Scenario #1 results in <u>no</u> loss of life, costing $0 per year.
2. Scenario #2 (a crash in an uninhabited area) also probably results in no loss of community members' lives (those who would contribute to the cost of a local hazard mitigation project with their taxes, donations, or other sacrifices), thus also resulting in expected annual costs of $0.
3. Scenario #3 (crash in a less-dense but inhabited area) might result in occasional loss of life – a person here, several people there – depending upon the exact circumstances of the crash. Based on the nature of the area and its population, some estimate might be made, such as that such a crash would result in an average of 2 deaths, 3 serious injuries, and 5 moderate injuries per event. With death costs estimated at $2.715 million each, serious injuries estimated at medical costs of $15,600 per person, and moderate injuries estimated at $1,560 per person (estimated values taken from FEMA guidance), these costs would total 2 times $2.715 million, 3 times $15,600, and 5 times $1,560, resulting in a total of $5.4846 million, which must be multiplied by the probability of that scenario occurring (.001 times .04 times .8 equals .000032) to provide the estimated annual cost of $175.51.
4. Finally, the costs for a "worst-case scenario" are estimated. If we suppose that scenario #4 above is likely to result in 80 dead, 40 serious injuries, and 50 moderate injuries, the costs add up to $217,902,000, the likelihood of occurrence is (.001 times .04 times .2) only .000008, and so the expected losses in a given year come out to be $1743.22 in this "worst-case" scenario.
5. Adding this to the costs from scenario 3 casualties, we find an estimated overall cost of $1918.73 per year. This should be added to the $63.84 total annual costs from property damage, and the $1982.57 result might justify a small mitigation project such as the installation of navigation/guide lights to help steer distressed planes away from critical and populated areas, if possible.

(If you decide to use this method to evaluate mitigation projects using a benefit-cost analysis, then the effectiveness of such a strategy in actually reducing the likelihood of a serious crash must still be considered. If it reduces worst-case scenarios by 70% (shifting crash sites from the 80:20 proportion to a 94:6 proportion of low-density to high density crash sites), there are still substantial expected annual costs from this hazard, but they have been reduced to $774.79, and this reduction of $1207.78 per year should be weighed against the costs of the hazard mitigation project and possible alternative uses of the money. It may be that a more beneficial project can be completed for a different hazard, with the same amount of money leading to greater benefits in mitigating a severe wind, flooding, or lightning hazard. NOTE: **These figures are merely for illustration purposes.** The example strategy of navigation/guidance lights would probably not actually reduce "worst-case" crashes to such a great degree!! **Actual statistics should be estimated from observations of pertinent conditions in your community, and from reliable sources of generalizable information on the frequency of, and damages from, hazard events.** Please continue reading in this appendix to get more information about benefit-cost analysis.)

Obviously, the ability to perform a detailed risk assessment like this is helped greatly by the use of spreadsheets and GIS, and by having a detailed community profile that will summarize all the critical facilities, population clusters, and special environmental areas that might be affected by a hazard. Even hazards that do not have any spatial variation within your community can and should be analyzed in terms of probabilities. For example, there may be an average of 10.5 heavy snow days and 21 moderate snowfall days in your community, each of which may have costs that can be estimated in terms of road clearance, closed schools, the capacity of identified snow storage areas, increased risk of power failures, increased risks to those with mobility limitations who are snowbound, increased transportation accidents, and so on. Once the various components of the hazard's impacts on your community are described, mitigation strategies that reduce the costs of at least one of these impacts can be assessed.

The following table is given as an example to summarize something that might have come from a detailed hazard analysis of a community's top hazards. Some other type of table, graph, or text may be used in your document to explain how you analyzed the subject, or a table like the one below can be used to summarize hazard potentials in your community.

EXAMPLE OF A RISK ASSESSMENT: PLANE CRASH SCENARIO IN FICTION COUNTY	annual chance	response costs & property damage	local casualty costs	other costs	Total costs from each scenario (sum of all estimated costs in columns at left)	Expected annual costs from scenario (total costs x annual chance)
Scenario #1 no crash, no areas hit	.999	0	0	0	0	$0
Scenario #2 crash, no inhabited area hit	.00096 (.001 x .96)	$25,000	0	?	$25,000	$24
Scenario #3 crash, inhabited area hit, not dense or critical	.000032 (.001 x .04 x .8)	$345,000	$5.4846 million	?	$5,829,600	$186.55
Scenario #4 crash, inhabited area hit, dense and/or critical	.000008 (.001 x .04 x .2)	$3.6 million	$217.9 million	?	$221,502,000	$1,772.02
						TOTAL annual cost (risk) from the plane crash hazard: $1982.57 (sum of all annual expected scenario costs, in the four columns above)

The table can have other costs (service disruptions or transportation delays, for example) included, if such information is pertinent and available. The end result is that a measurement of risk (in dollar terms) has been calculated. This allows the comparison of different hazards with each other, or the costs of a mitigation project to be weighed against its benefits. This analysis also shows that a community's hazards have been well thought-through, with detail that allows others to more easily become aware of potential community impacts. If there is some debate about the more subjective aspects of risk and vulnerability estimation, this technique provides a framework through which such disagreements can be negotiated—specific numbers may be raised or lowered based on negotiations among experts and officials. Even if the measurement of risk retains degrees of uncertainty, subjectivity, and imprecision, the community benefits from increased discussion and awareness.

In the plane crash example scenario that was just given, the principles of a method were illustrated that combines economic estimates with probability estimates, with a result that expresses overall risk in terms of an average ("expected") annual amount of damages suffered by the community. This calculated amount can be called "expected annual losses." It can be used to compare hazards to each other, and to see if the costs of mitigation projects are justifiable when compared to the costs of letting a hazard go unmitigated. **This appendix will treat all other hazards with a similar style of analysis—expressing risks in terms of dollars and probabilities.** This sort of approach is very similar to (and compatible with) the methods that FEMA uses to weigh the costs and benefits of a mitigation project when they are asked to approve it for funding through one of their hazard mitigation grant programs. **In section 2 of this appendix, information will be included about the values FEMA has determined are appropriate for estimating different types of disaster costs—from structural damages to road closures and loss of services.**

Each of the hazards that have been identified by the Michigan State Police Emergency Management Division will be listed below. Each listed hazard will have a description or discussion of how an analysis could be performed of the risks and vulnerabilities that it may pose to your community. In many cases, the analytic methods that are suggested are quite new, and therefore subject to refinement as may seem appropriate to how they affect your community. In addition, if your community has a specialized expert that is helping with some aspect of the hazard mitigation planning process, the information and methodology provided by that expert may be superior to the techniques suggested in this workbook. The guiding factor in using any analytic technique is whether it helps to *validly* explain the extent of risk, where the risk comes from, and how it might be addressed through hazard mitigation activities. At this time, many of the hazard descriptions in this workbook do not have precise and well-defined methods of risk assessment. Future editions of this workbook will probably include improved information and suggestions, as awareness of hazard mitigation builds and methods are eventually found that are readily applicable to it.

If effects may be felt across jurisdictional boundaries, it may be advisable for communities to coordinate their mitigation efforts with each other. At the very least, communities must consider whether nearby sites in other jurisdictions may pose some risks to them. Check with neighboring communities about their hazard mitigation plans, or the presence of hazards that could affect you. Regardless of how a hazard originated or what community has had primary responsibility for it, your community may calculate that it makes sense to help mitigate such hazards, so as to prevent future impacts and losses that may reach over jurisdictional lines.

Civil Disturbances
This hazard might be separated into several sub-categories of disturbance that could affect your community.

1. <u>Disturbances that center around a particular facility</u>: the facility could be a prison, a courthouse or other center of government, a stadium or other public meeting place, where large numbers of people may at some point gather in a disruptive fashion that is threatening to the community, its businesses, residents, or quality of life. Typically, a risk assessment would examine the history of the facility, and similar facilities in other communities. Such historical information might identify particular conditions that may cause collective behavior to get out of hand. The degree to which your community contains facilities and conditions that have been associated with civil disturbances will indicate the amount of risk that it faces from civil disturbances. As a mitigation strategy, your community would then wish to avoid or reduce conditions that have caused civil disturbances in the past, or in similar places. In areas where disturbances may be part of the expected activities associated with a facility, changes should be made in the design or location of the facility so that these activities can be accommodated or contained as much as possible. For example, a courthouse or political facility may be expected to occasionally draw crowds and protesters, and so an space might be provided and designed that would allow such activities to occur with minimal effects on surrounding areas. Similarly, concert arenas, race tracks, stadiums, fair grounds, and so on, can be expected to produce large amounts of noise and crowding, and should therefore be located and designed in ways that will enhance control over events and situations that have potential for civil disturbances. A special form of this kind of disturbance is located in or near Universities—the expected activity in such cases would be "parties" that may sometimes grow to a scale that is inappropriate for the environment to handle. After the size of (and historical precedents for) such parties have built up, their character may

change into that of a destructive civil disturbance. At such a point, the nature of such events may be only tangentially related to the characteristics of the area's long-term residents.

2. Disturbances that arise in general areas experiencing conflict and hardship: This refers to neighborhoods or regions that have experienced one or more economic, social, or political stresses such as poverty, ethnic intimidation, corruption and/or the notable presence of illegal activities. These ongoing conflicts and challenges may sometimes flare up into more widespread and blatant conflicts and unrest. The important things to recall about these sorts of civil disturbances is that it is the presence of these conflicts and problems (rather than a particular ethnic or demographic composition) that eventually generates broader disturbances. Care must be taken not to inappropriately "profile" areas based on characteristics of their residents. For example, gang-related activities in a particular area might be found to stem from the large number of unused buildings and abandoned properties that are found useful for alternative and illicit purposes, while actual residents living near such areas may feel powerless to change these circumstances.

3. Disturbances designed to interfere with normal business functions: Sometimes, protests are organized in a way that is deliberately designed to disrupt the normal operations of one or more businesses, and may also happen to disrupt surrounding business operations or traffic flows nearby. Many such incidents are political, and eventually addressed through court actions or legislative proceedings. Labor negotiations may have associated employee unrest, including strikes. Protesters may object to the existence of specific facilities or businesses, or their location in a specific area, and while seeking to make such a business or its associated activities illegal, may attempt to take more direct action against its employees or patrons. Typically, the perceived harm from such businesses are either from environmental impacts or injury to persons, or social impacts concerning the image or moral standards associated with an area. In other cases, a political demonstration may not have anything to do with the sorts of facilities or businesses in an area, but merely seeks the most crowded and inconvenient location so as to maximize the attention that it receives.

There is no specific "formula" recommended here for analyzing civil disturbance hazards, but it is probably helpful to have a historical approach be taken that specifically addresses the social conflicts and political controversies affecting disturbance-prone areas of your community. Mitigation activities—such as better location, screening and buffering around potentially disruptive or controversial businesses or facilities, or the clearance of abandoned, contaminated, or harmful sites—can be attempted to try to address underlying problems that may provoke or encourage such disturbances. The various costs of past events (crowd control, vandalism, arson, business disruption and closures, injuries, diverted traffic, negative economic impacts) can be estimated along with their past frequency (e.g. three times in the past hundred years) so as to produce an estimated annual cost, as described in the section on detailed risk assessment in Step 1c. The history of cities with similar conditions can also be analyzed in this way, because the risk of a disturbance may be present even though there have not yet been any events. This is particularly true for communities with newly-developed facilities, in rapidly growing areas, or experiencing significant social and economic changes. Their risk of civil disturbance may be increasing but there is not yet a local history of incidents that can be generalized from. The experiences of other communities that have gone through similar circumstances can be very valuable for mitigating risks and thus seeing improvements arise from past events and struggles.

Drought

Drought is a low-profile hazard that does not get a lot of public attention in Michigan, compared with the Rocky Mountain or Great Plains states. Nevertheless, years with significant drought have affected Michigan six times during the past 30 years, giving an estimated risk of a drought occurrence at 20% per year. Although the occurrence of drought may be lower for your community, and since droughts are not instantaneous hazards, they should not be glossed over in hazard mitigation planning.

When a drought takes place, there are myriad impacts that can result from the extended dry period. Impacts can be broken down into economic, social and environmental categories. First and foremost is the economic loss of crop production through lower yields, poorer crop quality, and reduced productivity of the land. (Michigan's fruit production is especially vulnerable to lesser yields, as was seen in a 2001 drought event that caused the destruction of one-third of the state's fruit and vegetable crop). Timber production is also reduced through possible forest fires/tree diseases, and fisheries also have lesser amounts of fish. The lesser production in the agricultural sector leads to income losses for farmers and industries dependent on agricultural products. Lower hydrologic levels lead to water shortages for municipalities and possible shutdowns of industries and businesses dependent on large volumes of water. The quality of water will diminish with lower levels, as well. Furthermore, tourism becomes hampered by lower lake and river depths, as fewer recreational opportunities become apparent. Severe and prolonged droughts could have catastrophic effects on the economy, as the adverse conditions lead to disruptions in the regional and national economy with widespread economic losses affecting daily distribution of goods and services.

Socially, there is a threat to public health and safety, as water shortages and decreased water quality raise threats of illness, land subsidence, and wildfires. Conflicts between water users can arise, especially when a river or lake has competing uses among municipalities, agriculture, industry, and recreational users. Water restrictions and limitations among residents also can change daily lifestyle patterns and create social unrest in severe cases.

Environmentally, a drought brings the aforementioned lowering of water levels and water quality for surface lakes and rivers, and strains the subterranean aquifers in the state. Animal and plant species populations decline and have a heightened risk for disease. Air quality is reduced from an increase of dust and pollutants in the air. Soil quality and quantity is also diminished due to enhanced erosion, especially around freshly exposed areas near to lowered lakes and streams.

How can your community plan for lessening the effects of a drought occurrence? A good way to start would be to analyze how often drought has occurred in your community. A local weather station or inquiry to the state climatologist may help you discover that information to determine what the exact risk may be for your area of the state. Once that is accomplished, then focus on drought monitoring and developing a drought contingency plan as part of your emergency mitigation plan.

Drought Monitoring

The process of drought monitoring is a simple way for your community to mitigate the effects of a drought. By examining many of the drought indices, you can get a grasp on the possibility of encroaching drought conditions. By examining such drought-related scales as the Percent of Normal, Standardized Precipitation Index, Crop Moisture Index, Surface Water Supply Index, and the Drought Monitor (all available from the National Drought Mitigation Center website, http://www.drought.unl.edu/index.htm), an idea of present conditions and forecasts are at your fingertips. Using these indicators given from the NDMC, you can determine how close or how far off drought conditions may be for the area. Depending on the readings and predictions from the indices, you can determine how much of a risk and what kind of potential losses may arise from year to year. Heading into springtime in a given year with above average precipitation lessens the threat of impending drought (and its consequences) while dry fall and winter conditions lead to a heightened awareness of potential summer drought conditions.

Drought Contingency Plan

Having a Drought Contingency Plan for your community is quite important in the event that a severe drought impacts your area. This plan should be a separate document detailing what steps need to be taken in the event of a drought. The plan should cover the following questions:

1) Where are primary water sources for the general population?
2) Where are alternative sources for water if the primary sources are inadequate for the community's needs?
3) At what point of lessening water resources do local water restrictions go into place?
4) Are there incrementally stricter water regulations related to drought severity?
5) At what point do water restrictions cease?
6) What are the costs of bringing in outside water to the community?
7) What is the hierarchy of water reception for residential, commercial, agricultural and industrial areas?
8) How will children, the elderly, the ill, and other vulnerable citizens be accounted for?

Overall, planning for mitigating the effects of droughts is very important, even if drought is considered a low-profile hazard and occurs infrequently. Your community does not want to be caught off-guard the next time there are drought conditions as there were in 1988. Having some contingency plans in place and monitoring the potential onset of the drought can reap benefits when a drought does settle into the state.

Earthquakes
Although earthquakes are generally not considered a major hazard in Michigan, other states have had so many problems with this hazard that very detailed techniques have been developed to estimate earthquake risks. Each area of the country has been assessed by geologists (according to types of bedrock, fault line proximity, and probably other factors) and sorted into general zones of earthquake risk. (For a national map showing this, see the web site at http://geohazards.cr.usgs.gov/eq/pubmaps/US.pga.050.map.gif .) These zones are expressed in terms of a probability that significant ground movements will be felt. For example, there may be a 10% chance of an area experiencing significant ground movement within a 50 year period, (which is similar to the "500-year" floodplain, since the annual probability of such an event calculates as roughly .0021). The other component of risk calculation would be to estimate the amount of damage that is likely when such an event occurs. Official measures use the concept of Peak Ground Acceleration (PGA, which is also abbreviated as %g). All that remains is to translate the severity of (PGA) ground motion into estimates of structural damages and other economic costs. The earthquake analyst should use historic data to estimate the extent to which different types of structures are affected by different severities of ground movement that are likely to regularly occur in your area. The extent of damage can then be expressed in terms of the value of the structure, its contents, and its economic importance to the community. FEMA has developed a computer application (HAZUS) to give estimates of these earthquake effects.

Michigan has a comparatively low risk of experiencing damaging ground movements. Because of this low risk, however, many designers and developers did not take into consideration the possibility that an earthquake *might* occur. Some of Michigan's communities may actually be quite vulnerable to earthquake effects—especially Michigan's underground utilities—if certain developed areas were not designed to withstand <u>any</u> ground movements. Most earthquake risk analyses in Michigan will start by identify facilities or infrastructure that *might* be at-risk, and then have engineers calculate the degree of actual vulnerability to those facilities. Engineers should be able to estimate potential damages and calculate structural reinforcement costs to see if earthquake mitigation measures are economically justifiable.

Extreme Temperatures
Temperature extremes are broken down into two categories: extreme heat and extreme cold. Both extremes can last for weeks, without any advance warning and in the middle of a seemingly normal weather pattern. Additionally, both extreme heat and extreme cold can cause loss of life to vulnerable populations, sporadic damage to infrastructure, and disruptions to schools and businesses. Risks and potential costs of each type of extreme temperature hazard are given below.

Extreme Cold

Extreme cold is primarily associated with the wintery months of November through March and categorized by temperatures plunging near or below 0°F. Although all counties in Michigan are susceptible to harsh subfreezing temperatures, counties in the North Central and Upper Peninsula of the state typically have more annual days of extreme cold than the southern portions of Michigan. Periods of extreme cold are risky for those in rural and in urban areas. Frostbite and hypothermia is common in rural areas where people are trapped outdoors and do not adjust properly to the temperatures. Even indoors, hypothermia is a concern for individuals living in inadequately heated apartments or rooms. Loss of life can occur with either of these situations. Damage to buildings and pipelines can also occur in bitter cold conditions, creating expensive repairs and potential days of business and school shutdowns.

To mitigate the effects of the unfavorable cold temperatures, communities should make sure that housing codes are appropriate and that adequate furnaces are in place in apartment dwellings. Inspections of vulnerable and outdated infrastructure should be made in the fall season, before winter sets in. In addition, proper insulation of piped areas can prevent water main breaks. Monitoring the extent of the bitter weather can be done by regularly checking the National Weather Service stations in Michigan (in Marquette, Gaylord, Grand Rapids, and Detroit) at www.crh.noaa.gov. A risk assessment should calculate the likelihood of such incidents and the number of days of extreme cold likely to be experienced in your community each year. It should then take account of past losses and harm caused by such events, and determine who or what is still vulnerable to such conditions today.

Extreme Heat

Extreme heat occurs mainly during the summer months of June, July, and August and is marked by temperatures above 90°F. Counties in the southern half of the state have the highest frequency of days exhibiting extreme heat. Urban areas are especially prone to days with soaring temperatures, with incredibly hot temperatures near to concrete and asphalt surfaces. Individuals working outdoors, the elderly, and children need to be accounted for during oppressively sizzling conditions, as they are most at risk for heat exhaustion, and fatal heat stroke. Scorching weather also puts a strain on the energy demands for areas, as air conditioning becomes a necessity for vulnerable populations. Possible shutdowns of schools, colleges, and industries can occur during these times.

To mitigate the extreme heat of summer, communities should have a contingency plan in place to protect those people who are most vulnerable to the heat. These contingency plans should include: a set up of "cooling stations" where people can go to get out of the heat; a hierarchy of closings for industries, businesses, and schools during shutdown periods; and a means of exclaiming the dangers of the conditions, perhaps through local media. Monitoring of the dangerous conditions can also be done through the National Weather Service website. A risk assessment should calculate the likelihood of such incidents and the number of days of extreme heat likely to be experienced in your community each year. It should then take account of past losses and harm caused by such events, and determine who or what is still vulnerable to such conditions today.

Fire Hazards: Scrap Tire Fires

Rather than causing structural damages and loss of life, the majority of the costs of a scrap tire fire are economic and environmental. A scrap tire fire may require the temporary evacuation of some residences and businesses, and the closure of some roadways—all of which have calculable costs. The biggest headache for a community may be the difficulty in controlling and extinguishing these fires, which can occupy emergency responders for days! For example, a 1997 fire in Osceola County cost about $300,000 to extinguish, and used 478 firefighters from 34 different departments. Such costs can be extremely demanding on rural counties that generally have limited resources. If this type of fire might have an effect on nearby populations, businesses, or environmentally sensitive areas, risk estimates should include these in their consideration of the likely costs such a fire would cause. The odds of a scrap tire fire starting may be difficult to estimate from a theoretical perspective but could be hypothetically approximated by the use of historical fire occurrence data.

Fire Hazards: Structural Fires

Information from code enforcement officials can be very helpful in assessing structural fire risks. Conditions that are likely to affect fire risks include type of building construction (frame, masonry, joisted masonry, etc), age and condition of structure, structure location and pertinent crime rates (i.e. arson), fire protection coverage (average response times, distance from hydrant), proximity to other structures or fire-prone wildlands, presence of fire prevention and suppression equipment, and type of occupancy (for commercial buildings). The type and condition of a structure's heating system, electrical capacity, and similar design and maintenance issues may also be considered. Naturally, a consideration of all of these would require a lot of information, but considering just a few of these variables and tapping the knowledge of local inspectors can do a lot to pinpoint area needs.

Historical records may be usable for accumulating statistics that estimate fire risks. Records for other jurisdictions that are similar to yours may be very useful for adding to the information in your own local history. The presence of historic downtown "main street" areas with rows of attached structures may be a concern unless modern firewalls and fireproofing has been undertaken between units. Some areas may have higher rates of arson and need to be considered in terms of reducing human-caused risk factors. Other structures may be located in the wildland/urban interface and thus face risks from wildfire events.

Fire Hazards: Wildfires

FEMA (and others) have created fairly detailed methods for estimating wildfire risks. The information in this workbook summarizes that given in FEMA publication 386-2 ("Understanding Your Risks"). It primarily uses weather, topography, and land cover (fuel) data to estimate wildfire risks. (Some alternative models can be explored at http://www.seawfo.noaa.gov/fire/olm/nfdrs.htm.) The first activity is to map the "fuel model" categories in your community. This process currently sorts all areas into three "fuel model" categories based on the types of vegetative land covers that could act as fuels in a wildfire event. Here is a summary of the three fuel model categories described by FEMA:

LIGHT FUEL CATEGORY – Covers any of the following general descriptions of vegetation in an area:

1. Predominantly marsh grasses and/or weeds.
2. Mosses, lichens, and low shrubs are the predominate ground fuels, but have no overstory and/or occupy less than one-third of the site.
3. Grasses and/or forbs predominate. Any woody shrubs will occupy less than one-third of the site. An open overstory of conifer and/or hardwood trees may be present.
4. Brush, shrubs, tree reproduction or dwarf tree species predominate, but this is only considered light fuel if the average height of woody plants is under 6 feet, and they occupy less than one-third of the site.
5. Deciduous broadleaf tree species predominate and the area has not been thinned or partially cut (which would create a higher-risk fuel source called "slash.")
6. Conifer species predominate, but the primary ground fuels are grasses and forbs. If the primary ground fuels are duff and litter, branchwood, and tree boles, then the area can only be considered "light fuel" if pine needles are 2 or more inches in length, the overstory is not decadent, and there is only a nominal accumulation of debris.

MEDIUM FUEL CATEGORY – Covers any of the following general descriptions of vegetation in an area:

1. Mosses, lichens, and low shrubs are the predominant ground fuels, and an overstory of conifers occupies more than one-third of the site.
2. Grasses and/or forbs predominate, with woody shrubs occupying between one-third and two-thirds of the site.
3. Brush, shrubs, tree reproduction or dwarf tree species predominate, and woody plants are either greater than 6 feet in height, or cover more than one-third of the site.
4. Conifer species predominate, and the understory is dominated by lichens, mosses, low shrubs, woody shrubs, and/or reproduction. (If the primary ground fuels are duff and litter, branchwood, and tree boles, and pine needles are less than 2 inches long, then the overstory must not be decadent, and there must be only a nominal accumulation of debris.)

HEAVY FUEL CATEGORY – Covers any of the following general descriptions of vegetation in an area:

1. Deciduous broadleaf tree species predominate in an area that has been thinned or partially cut, leaving slash as the major fuel component.
2. Conifer species predominate, with duff and litter, branchwood, and tree boles as the primary ground fuels, and an overstory that is overmature and decadent, with a heavy accumulation of dead tree debris.
3. Slash is the predominant fuel in the area. (Counts as heavy fuel at any level of loading, regardless of whether settling has been significant or slight, and whether foliage is attached or falling off.)

The United States Department of Agriculture has created a general map of fuel models, which can be accessed at their web site at http://www.fs.fed.us/land/wfas/nfdr_map.htm. Since they are assessing nationwide risks, local or state resources will probably be needed to supplement this source in order to accurately assess a community's specific fuel model areas in your local hazard mitigation plan.

FEMA's wildfire model then combines these fuel type areas with assessments of local topography and weather patterns, to identify overall risk categories (called "moderate hazard," "high hazard," and "extreme hazard.") Topographic information provides three land categories, based on the severity of slopes present in an area. Low slope areas have slopes less than or equal to 40%. Moderate slope areas contain slopes measuring from 40% to 60%. Steep slope areas contain slopes grater than 60%.

Weather information can produce estimates of the number of days per year with "critical fire weather" conditions. FEMA has stated that a local or state fire marshal, forestry department, or department of natural resources can help in determining the number of days per year that critical fire weather is experienced in your area.

Overall categories of wildfire risk (moderate, high, and extreme) are given by the following FEMA table:

	Frequency of Critical Fire Weather								
	1 day per year or less			2 to 7 days per year			8 or more days per year		
Fuel Classification	Slope =<40%	Slope 41%-60%	Slope =>60%	Slope =<40%	Slope 41%-60%	Slope =>60%	Slope =<40%	Slope 41%-60%	Slope =>60%
Light Fuel	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	High
Medium Fuel	Moderate	Moderate	High	High	High	High	Extreme	Extreme	Extreme
Heavy Fuel	High	High	High	High	Extreme	Extreme	Extreme	Extreme	Extreme

Additional factors that increase fire risk and may be included in a model include lightning (see http://www.fs.fed.us/land/wfas/wfas24.html) and human factors such as the number of persons residing in, camping in, visiting, or traveling through an area. Such persons may increase fire risks through carelessness or ignorance, while other persons (including residents and fire spotters) may reduce risk of uncontrolled wildfire in an area, through their ongoing fire awareness, prevention, and response activities. It also makes sense to take into account the type of fire-fighting personnel, equipment, expertise, and related resources (such as water) that are available to a community, or lacking in adjacent communities (from which a fire might spread).

Vulnerable structures are those located in or near a potential wildfire area, unless they have taken special steps to become "Firewise" (as described in the Hazard Identification section of this workbook). Nonflammable roof and patio materials, clearance of vegetation and maintenance of a defensible space around structures, means to provide and facilitate site access by emergency responders, and so on, will make a structure potentially able to withstand wildfire events in its vicinity. Structures that are located in a wildland/urban interface area should be evaluated for these sorts of site features that will exacerbate or minimize their vulnerability. Certain design or landscaping features can render an at-risk structure completely vulnerable to any nearby wildfire event, and thus should be prioritized for wildfire mitigation strategies.

Although risk-estimation models exist, FEMA states that there are no standardized methods for estimating the amount of damages and economic losses that a community will sustain from a wildfire event. Hopefully, a study of the risk assessment options described in this section will enable your community to estimate the frequency of its wildfire events, based on fuel types and weather patterns. Structures in at-risk areas can then be individually assessed according to their "Firewise" characteristics. (These will be rough estimates of vulnerability based on the degree to which wildfire mitigation steps have been used at that site: see the fire protection steps at the FIREWISE web pages at http://www.firewise.org/pubs/protect/.) Structures that are not at all Firewise can be considered at-risk for total losses in a serious wildfire event. Structures that are partly Firewise should be at significantly lowered risk and thus the chances of a total loss should be lower. These estimates can be converted to dollar values (expected annual losses, as described in the Risk Assessment section) by using information about housing values, estimates about the value of house contents, the value of interrupted services, evacuation, road closures, and displacement. (Estimates for all these types of losses and costs can be found in the second section of this appendix.) The value of total potential losses for each property in an at-risk area should be reduced in proportion to the extent to which it is Firewise. Overall loss calculations will therefore take the annual probability of a fire event in vulnerable areas and multiply it by the percentage of that vulnerable area that will likely be affected (this will have to be estimated based on available wildfire response capabilities, or can be estimated from analyzing the extent of past wildfire events and how difficult they had been to control). The percentage of the vulnerable area affected can be considered to also represent the odds of a particular structure in that area being placed at risk, and so each at-risk structure can then have its value (after being reduced an appropriate percentage that reflects its Firewise characteristics) multiplied by that calculated risk of being involved in a wildfire event. The total of all individual structural losses can then be totaled to estimate an entire community's annual expected losses from wildfires. (A more detailed risk model is at http://www.firewise.org/pubs/WHAM/nfpa/.)

Here's an example. Let's say that a county identifies two areas that are at high risk and one that is at moderate risk from wildfires. It then identifies the number of structures in each at-risk area and studies the extent to which each can be considered "Firewise." The values of these structures are found from assessor's data, or estimated from other sources such as the U.S. Census. FEMA methods are used to estimate additional losses to each structure's contents. Estimated expected losses to a structure and its contents are reduced in proportion to the extent that it is considered Firewise. These measures are combined to produce values representing expected annual losses and costs from wildfire hazards. The following table provides an example, using fictional data.

EXAMPLE OF WILDFIRE ANALYSIS IN TABLE FORMAT

Area/structure	Annual chance of wildfire event in that sector of the county	Chance of wildfire actually affecting the area containing the structure	Value of structure and its contents	Extent to which structure is FIREWISE	Estimated expected damages per event (value reduced by % FIREWISE)	Estimated Annual expected damages (damages X probability)
455 Fiction Ave.	.05	.09	$134,000	90%	$13,400	$60.30
475 Fiction Ave.	.05	.11	$175,000	0%	$175,000	$962.50
480 Fiction Ave.	.05	.15	$90,000	50%	$45,000	$337.50
1055 Faux Blvd.	.07	.35	$210,000	20%	$168,000	$4116.00
916 Alias Ave.	.07	.40	$156,000	15%	$132,600	$3712.80
924 Alias Ave.	.07	.40	$185,000	25%	$138,750	$3885.00
221B Baker St.	.01	.01	$40,000	99%	$400	.04
TOTAL for area						$13,074.14

This sort of calculation can be compared with the costs of a mitigation project. For example, if a firebreak costs $30,000 to create for the area of the county with the structures listed above, and reduces the annual chance of a wildfire in that sector of the county (from .05 and .07 to .01, in the first column), this would reduce annual expected damages in the area from the current total of $13,074.14 to $1,945.46, the expected annual savings from mitigation would be about $11,129. As long as the firebreak area will be effective for at least several years, and maintenance costs are not too expensive, it will clearly be an effective mitigation strategy that will be well worth its price. (Future costs of firebreak maintenance, and expected wildfire damages in future years, should be "discounted" as described at the end of this appendix, in the section called "Linking your Hazard Analysis with Benefit-Cost Analysis.")

Flood Hazards: Dam Failures

Potential damages from dam failures can be estimated by calculating the dam's "hydraulic shadow," which means the area of land that would be inundated with water were the dam to fail completely. Studies may already have been done for high-hazard dams. (Low hazard dams can probably fail or be removed without much harm to nearby populations, but are worth checking to see if a couple of occupied structures are nearby or have been developed since the dam was classified as low hazard.) The National Inventory of Dams contains useful starting information, including dam hazard classifications. This information can be obtained upon request from MSP-EMD, by contacting Mike Sobocinski at (517) 336-2053 or at sobocinm@michigan.gov. Once estimated flood depths are found, the analysis can proceed in a manner similar to that of riverine flooding (below). Due to the possible extra effects of flash flooding and wave action from a catastrophic dam failure, remember to treat parts of the hydraulic shadow area as floodway areas rather than floodplain. Damages will be greater from flash flood types of events than they would from gradual floodplain inundation.

The risk of dam failures should be calculated, where possible, from past occurrences. If your community has had no history of dam failures, you may wish to examine the histories of similar types of dams (based on size, construction, ownership, maintenance schedules) and use that information to estimate the annual chance of a failure. Remember that not all failures result in flooding—many failures are caught in time to prevent flood damages, but still have costs associated with emergency response and repairs. It makes sense to calculate costs from different types of events, as shown in the plane crash example at the start of this appendix. Most years, there will be no incident. If there is an incident, it will probably be relatively minor. The worst case scenario would involve catastrophic dam failure. It may be useful to combine your analysis of dam failure events with your community's assessment of terrorist and sabotage risks.

Flood Hazards: Riverine and Urban Flooding

Riverine flooding is a hazard that has been modeled for many decades now, and has some of the clearest methods of detailed analysis. Communities that are members of the NFIP probably have floodplain maps (called Flood Insurance Rate Maps, or FIRMs) that show where the floodplain areas are in the community and provide Base Flood Elevation (BFE) measurements. These calculations are based on surveying the topographical, hydrological, pedological, and land cover characteristics of the area's watershed. The result is a statistical model—a 100-year floodplain area has a 1% chance of flooding in a given year, and the BFE is the water depth associated with an event of that probability. Some areas may flood less frequently, such as a 500-year floodplain which has a 1-in-500 chance of flooding in a given year. The names "100-year" and "500-year" can be very misleading. A "100-year" level flood may occur several times in a century, just as it is possible to flip a coin and get tails many times in a row. For detailed analysis of flooding, the basic principle of risk is that there is a 1% chance per year of flooding that is at the BFE level. For example, if BFE is 365' and the elevation of a structure's first floor is 363' above sea level, then the result would be floodwaters that are two feet over the ground floor of that structure. Lesser flooding is likely to occur with even greater frequency—if two feet of floodwaters hit that structure with 1% probability, the likelihood of getting just a few inches of floodwaters is even greater in a given year. Conversely, the likelihood of flooding that has three or four foot depths is far less than a 1% annual chance. FEMA models for flooding divide these events into different degrees of severity, based on their likelihood of annual occurrence. A few inches of water may be a "10-year" event in one area, but a "100-year" event somewhere else. Within the same floodplain area, a structure's elevation (and whether it has a vulnerable basement) may make all the difference between suffering severe damages, and experiencing no damages. Ideally, flood risk information can be combined with structural information (such as might be available through a building department or assessor's office) and a Geographic Information System (GIS) could make the analysis of such information easier.

Once risk categories have been established for vulnerable structures, the amount of damage from flood events can be estimated using FEMA techniques. The basic technique is to find the replacement value of the structure, and to estimate damages by equating different flood depths with appropriate percentages of that replacement value. The following table estimates damages to structures, in terms of a percentage a building's replacement value, for different flood depths and structure types. (This table was adapted from Flood Insurance Administration guidance, based on historical averages from observed flood damages.)

FLOOD DAMAGE ESTIMATION TABLE
(Numbers given are damages as a percentage of the structure's replacement value)

	Type of structure					
Flood depths (depth of flooding in feet)	1 story, no basement	2 story, no basement	Split-level, no basement	1 or 2 story with basement	Split level with basement	Mobile home
Under ½ foot, in basement only	0	0	0	4	3	0
About 1 foot, in basement only	0	0	0	8	5	0
2+ feet in basement, <½' surface	9	5	3	11	6	8
About 1 foot flooding at surface	14	9	9	15	16	44
About 2' flooding on ground floor	22	13	13	20	19	63
About 3' flooding	27	18	25	23	22	73
About 4' flooding	29	20	27	28	27	78
About 5' flooding	30	22	28	33	32	80
About 6' flooding	40	24	33	38	35	81
About 7' flooding	43	26	34	44	36	82

NOTE: Since replacement value may exceed the current market value of a structure, damages greater than 50% of replacement value can be considered a total loss of the structure, unless special historic or service functions require that additional expenses be undertaken to repair and preserve it.

In addition, damages to the contents of structures can be estimated, by assuming that their value is 30% of the replacement value of the home, and then assuming that damages to those contents will be 1.5 times the percentages listed in the table above. This simple formula should be adequate for residential losses. Loss of contents in commercial facilities hopefully can be assessed more accurately by business owners or organizations participating in the development of your plan. Other damages and costs could be to public facilities and infrastructure, road closures, diverted traffic, loss of rental income, and so on. Please consult Section 2 of this appendix for more information on estimating the value of those sorts of costs.

NOTE: The replacement value of a residential structure can be estimated, where information is not readily available. Construction costs for residential structures will typically range from $75 to $100 per square foot. The typical price of $85 per square foot might be used unless you know that your area's costs are substantially higher or lower than average. This price can then be multiplied by the approximate square footage of residential use. For example, a 1000 s.f. house would have an estimated replacement cost of $85,000.

"Urban flooding" may involve low-lying areas that collect runoff waters even though they are not adjacent to drains or bodies of water. Information on the topography, soils, and impervious ground surfaces in your area can help to identify areas at risk for this type of flood hazard. Other kinds of urban flooding stem from flaws or shortcomings in existing sewer infrastructure. Some flood events may come from undersized or poorly designed sewer systems that cannot always process the amounts of precipitation and runoff that affects an area. Other events may have less to do with system design than with the collective effects of land use and development trends, illegal diversion of water, or actions that plug storm drains or otherwise interfere with system function. In some cases, flooding may result from power failures that temporarily shut down needed pumps and other facilities. (Backup systems can be a vital flood mitigation strategy in such cases.) Many communities are in the process of upgrading their systems, separating combined sewer systems (in which storm and sanitary sewer systems share many of the same components), and enforcing local codes, but have not yet achieved the long-term benefits that such actions will produce.

Some forms of flood damage even come from the decisions of individual homeowners and must be addressed on that level. Proper landscaping and downspout placement can prevent rainwaters from pooling around a structure and seeping into a basement. The use of sump pumps and sewer backflow preventers can prevent a great deal of the damages that are reported each year. Property developers and purchasers should be aware of the possibility of flooding in many areas, and should either locate their homes outside of risk areas, or engineer them to be unaffected by such events. This is an especially important concern in areas that are scenic and desirable because of their riparian locations. Some of these individual-level decisions and risks can be difficult to assess, but should be discussed in the flood analysis section of a plan, to increase public awareness and encourage individuals to be proactive and responsible.

Flood Hazards: Shoreline Flooding and Erosion
Shoreline flooding can be treated in a similar manner to riverine flooding in that there may be specifically identified shoreline areas that have significant flood risks, as shown on NFIP maps. In some cases, these areas may suffer additional damages due to wave action and seiche activities on the Great Lakes. It will be useful to supplement NFIP map information with a historical assessment of actual damages or water levels that your shoreline properties have experienced.

Shoreline erosion hazards typically involve the loss of property as sand or soil is removed by water action and carried away over time. Erosion effects that are experienced along rivers may be included in this category of hazard. Worst case scenarios typically involve occupied structures that, over the years, have had adjacent lands eroded away and now stand perilously close to waters or cliffs. The foundation of a structure, or underground utility pipes in the area, may become fully exposed and vulnerable to weather, extreme temperatures, water damage, or other sources of risk.

Another frequent situation in Michigan involves shoreline roadways whose banks erode and cause the road surface to crack, become unstable, or more prone to deposits of sand, snow, water and ice from nearby beaches and water bodies. The costs of delayed traffic and detours can be counted in your analysis, using rates as suggested in the second section of this appendix (Estimated Costs for Hazard Damages and Other Effects).

Hazardous Material Incidents: Fixed Site
Individual firms doubtlessly vary a great deal in their safety records, just as they vary in the types and quantities of hazardous materials that they handle. There are separate plans (called Emergency Site Plans) that should exist for each facility that qualifies as a "SARA Title III (Section 302)" site because of the types and amounts of extremely hazardous substances it uses. Local Emergency Planning Committees (LEPCs) should exist in any community that has handlers of such materials, and the LEPC would then help hazard mitigation plan writers to gain access to and evaluate the Emergency Site Plans pertaining to your community (either within it or near enough to be a potential hazard). One of the useful items included in the standard Emergency Site Plan form is an estimated evacuation area—if a harmful release or incident were to occur at the facility, an estimate has been made about the potential impact area based on the types and amounts of extremely hazardous substances being used there. Use of GIS can be helpful since Section 302 sites can be located spatially and then ringed with a buffer representing the identified evacuation zone. A vulnerability assessment would primarily be based on the development that exists within that zone—especially if vulnerable populations are located within that area, such as schools, hospitals, other medical facilities such as blood banks or kidney dialysis centers, high-rise senior facilities, and day care centers.

The probability of an incident might be assessed from historical records of industrial accidents or chemical releases. Wide variation in estimates is likely depending on whether the history of an entire industry or only a particular site is used. Often, a local site may appear to have an incident-free history, but the risk cannot be assumed to be zero. Information from MIOSHA and EPA may be valuable for estimating risk probabilities.

Hazardous Material Incidents: Transportation

This analysis should begin with an assessment of transportation hazards (see the section on Transportation Accidents later in this appendix) and then add on a consideration of the types of materials that are being transported through an area. With railroads, records can hopefully be located that allows an estimate of what the effects of a train derailment might be. Roadway accidents would be assessed in terms of the sorts of materials being transported through the community by truck. In many cases, this will be directly related to the types of facilities that trucks are driving to and from. In more complicated cases, as with a major expressway leading to or from a large metropolitan area, some estimates might be made from generalizations of the sorts of materials that serve the industries located in the metropolitan areas. Much of these considerations might be simplified by taking a worst-case scenario (the worst known types of materials legally transported by truck in the United States) and using GIS to create buffers around interstate highways to reflect such a worst-case risk. Such buffering might be illuminating if there are vulnerable populations located in the likely evacuation area of a potential spill on that highway. Analysis of this hazard thus combines the techniques of analyzing fixed site hazardous materials incidents (described previously) and the assessment of general transportation risks on roadways and railroads. MDOT data can be useful to assess risks associated with different types of vehicles, transportation planning information can be acquired from Regional Planning Offices (see page 10), and EPA/OSHA sources can help to assess the effects of the hazardous materials themselves once released. For more information on occupational safety records, extremely hazardous substances, and transportation safety records, please refer to the appropriate sections and references in the Hazard Identification section of this workbook (under the subsections of Hazardous Material Incidents, and Transportation Accidents).

Infrastructure Failures

Whether the failure of electrical power, telephone, natural gas, water, sewage disposal, or transportation systems occurs as a primary stand-alone incident, or if the hazard occurs as a secondary result of extreme temperatures, snowfall, flooding, or winds—the risk of infrastructure failures is large. Infrastructure failures can affect hundreds of thousands of Michiganders when the conditions are "right" for a loss of critical systems. Melted transformers, ruptured pipes, crumbled bridges, and exploded transformers can inconvenience or wreak havoc around the nation and the state, depending on the severity of the problem.

The risk of infrastructure failure grows each year, as physical and technological infrastructure gets steadily more complex, and the interdependency between various facets of infrastructure (like pipelines, telecommunications lines, and roads) becomes more intertwined. Additionally, essential repairs to vulnerable and aging infrastructure do not keep up with the growing volume of rail lines, electrical components, bridges, roads, sewers, etc. in need of repair. Because of these reasons, large-scale disruptions in various components of infrastructure are much more possible today than ten or twenty years ago. The risk of failure will continue to grow, and such major disruptions could lead to widespread economic losses, limit security, and altered ways of life.

Infrastructure failures can occur at any time and in any place in the state of Michigan. The metropolitan areas and the greater Detroit area are the most susceptible to interruptions in infrastructure, due to the additional volume of critical components of transportation, power, water, and telecommunication networks. Residents of these areas are also less likely to have adequate measures to "get through" infrastructure failures, with a lack of generators, wood, and fireplaces. Economic losses with incapacitated business and industry are much greater in these areas as well. In northern regions of the state, there are fewer networks of infrastructure, but greater geographic areas are affected during infrastructure failures. Downed lines or blocked roads affect many more square miles than a similar occurrence around Detroit, but there are far fewer individuals and businesses at risk.

To assess the risks of infrastructure failure in your locale, an examination of past infrastructure failures is very important. Have their been numerous power outages whenever there are severe winds? Do extremely cold or extremely cold temperatures strain or cause failures of water, gas, and electric resources? How often have various sewer, water, and electric lines been renovated? Is there a tree management program in place to limit structural damage during thunderstorms and winter storms? What are local regulations for new infrastructure? Questions such as these can be answered by contacting utility companies and municipal public services (city water and sewage). These companies/departments should have records of power and water failure incidents and can provide some answers on the age of infrastructure components. Information on service providers, service areas, and infrastructure details can be found through the Michigan Public Service Corporation, at www.michigan.gov/mpsc.

Transportation infrastructure concerns can be discovered through city and county road commissions, and through MDOT. Traffic volumes of major roads and information on recent and future projects can be found through the MDOT website, at www.michigan.gov/mdot. Contact of local engineering firms may be of interest to determine if there are any recent publications or studies of various infrastructure components in your community, as well.

Nuclear Attack

This hazard is not really one whose risks are customary to analyze at the local level. During the Cold War, the policy of "mutually assured destruction" meant that even communities that had no direct targets anywhere within their vicinity would nevertheless be profoundly or fatally impacted by the massive and widescale effects of a full nuclear exchange between the United States and Soviet Union. The effects of being struck by as many as 3,000 warheads (each of which would be much more powerful than the atomic blasts seen at Nagasaki and Hiroshima) would mean an almost inconceivable change in world conditions that few plans could attempt to adequately address. Now that the Cold War period has ended, different sorts of planning may again be appropriate for this hazard. The possibility exists of being selectively targeted by a hostile nation that has both nuclear arms and the ability to deliver such devices to a target in Michigan. In the case of a country such as China (which has hundreds of nuclear weapons but not necessarily enough to assure total destruction of an enemy, and not all of which are equipped for intercontinental ballistic missile delivery) there may be a selective targeting of specific military, governmental, and population centers. For such a scenario, please consult the map of identified Michigan targets in the Michigan Hazard Analysis document (EMD-PUB 103). Fortunately, China is not currently seen as an extremely high risk for engaging in nuclear conflict. An accidental release of Russian weapons might result in some comparable targeting scenario, if there are still missiles set up for automatic targeting of pre-identified American sites. This might occur if some aspect of their current security mechanisms were to break down, or if some false alarm were to prompt a limited response to a perceived threat before the false information could be corrected. The result might be equivalent in effect to a limited nuclear exchange or an attack by a less-fully armed adversary such as China, in which a large but limited number of missiles strikes key targets throughout the nation.

For this sort of scenario, local vulnerabilities would be assessed in terms of proximity to highest-priority enemy targets (those with the greatest military, economic, and socio-political impacts). The ability to shelter or evacuate people would clearly be important. The ability to maintain government functions and social services would be similarly important. The protection of utilities, transportation capacity, and information systems, from direct physical effects and the effects of an electromagnetic pulse, would also be worth considering. Since there is no known way to validly assess the probability of such international conflicts, most mitigation strategies would be prompted by and originate from federal initiatives and defense priorities—the "risk" part of a local hazard analysis on this topic would therefore probably be missing due to lack of information, but the "vulnerability" portion can still be assessed in high-risk areas.

A new nuclear threat that has recently emerged concerns the possibility that one or more nuclear weapons might be used in an attack by international terrorist groups, or the activities of domestic actors, that might eventually be able to acquire and misuse nuclear technologies and detonate a device within our country, just as conventional explosives were used in Oklahoma City and in the 1993 detonation at the World Trade Center. The risks from such scenarios may now be worth considering in light of new Homeland Security concerns and possible escalations of the War on Terror. There is a separate section in this appendix dealing with Terrorism/Sabotage, and that section should be referred to, with the consideration that known targets from a Cold War nuclear attack scenario may still be helpful in identifying high-risk targets for a lower-level terrorist attack. Many Cold War scenarios will need to be updated to reflect the fact that some identified targets may no longer have military significance and thus would no longer have a reason to be deliberately targeted (programmed targeting routines from an automated Russian launch now being the only reason they might still be hit).

The presence of fallout shelters, or makeshift substitutes for them, would be a key factor of analysis. In addition, the ability of current transportation systems to handle mass evacuations would be another critical factor in reacting to a threatened or impending nuclear detonation. The presence of redundancies (backup systems) in your area's infrastructure and critical services would be another means to assess local vulnerability to a nuclear attack.

Nuclear Power Plant Accidents
For those communities that are within the Emergency Planning Zones of a nuclear plant, there should be plenty of information and analysis already available regarding this hazard. Writers of the community's hazard mitigation plan should consult with those who are involved with the nuclear facility's emergency planning. It may not be necessary to duplicate this existing information in the local hazard mitigation plan.

Oil and Gas Well Accidents
As with hazardous material hazards, it can be difficult to accurately assess incident probabilities for oil and gas wells, but some indications might be gained from existing OSHA data. As related in the section on hazard identification, information about the location of wells is available since permits needed to be issued before they are dug or drilled. If permit sites are near developed or potentially sensitive areas, specific inquiries can then be made with MDEQ to see if the permit actually resulted in a well being created, whether the well is still open or has been capped, and whether open wells have been known to contain hydrogen sulfide. Wells that are open and potentially hazardous should be reconsidered if they are located very near to vulnerable populations or densely developed areas.

Petroleum and Natural Gas Pipeline Accidents
Although no convenient source of statewide pipeline information could be found, hopefully it will be easier for planners to obtain information on pipeline locations at the local level. In general, an analysis will recognize the virtues and necessity of using pipelines, but will guide their future placement based on a consideration of population densities and environmental conditions. The potential of an accident to affect groundwater or public safety should be considered, along with the relatively low risk of incident (when compared with surface transportation options). As with the analysis of transportation accidents involving hazardous materials (see that section) it should be possible to estimate risks based on the location of pipelines and the type and volume of materials transported. Pipelines have built-in safety features to limit accidents to specific sites, rather than system-wide incidents. Nevertheless, an accident can occasionally have very dangerous results, and vulnerabilities near the pipeline route should definitely be considered when new developments are proposed.

Public Health Emergencies
Local public health officials can be consulted to see what vectors/media of disease transmission are present in your community, and what resource deficiencies might exist related to emergency-level public health concerns. In addition to the standard epidemiological approach, attention should also be given to the possibility of deliberate contamination, sabotage of vital facilities, or releases of dangerous biological agents (see the next section). As with terrorist planning information, many utility providers consider pipeline location information to be sensitive and inappropriate for general distribution, and care should be taken about the treatment of such information in a public document. Please see the material at the end of Appendix C in this workbook about recent changes in the Freedom of Information Act (FOIA) and how it may affect your community's planning process.

Sabotage/Terrorism
This is a hazard which poses serious problems in terms of realistically estimating likelihood of occurrence. However, a recent and ambitious attempt to model the risks of terrorism, and local vulnerabilities to it, has been produced by the Office of Justice Programs. Introductory information on the "Threat and Risk Assessment" process can be found at http://www.ojp.usdoj.gov/odp/docs/fs-state.htm and more detailed modules can be accessed by authorized persons through the appropriate link at the bottom of the http://www.ojp.usdoj.gov/odp/assessments/definition.htm site. One aspect of the assessment deals with first responders (law enforcement, emergency fire and medical services) and another deals with public health risks. The assessment tends to take a "bottom-up" approach by considering what local groups have demonstrated the capability of causing harm, and what local features might provide vulnerable or politically significant targets. While arguably not yet developed to the point of complete objectivity, such an assessment can be extremely helpful in establishing priorities and determining where preventive efforts are likely to be most needed and helpful. Vital infrastructure such as bridges, dams, and pipelines might be found to need increased security. Politically significant facilities may also be identified.

This is a topic that may not be appropriate to include in your community's multi-hazard mitigation plan, due to the problems of keeping sensitive or confidential information from being misused, but at the same time obtaining needed input and public approval for your community's plan. This hazard might be included as an appendix that could be separated from the main document when given public scrutiny. Please see the material at the end of Appendix C in this workbook about recent changes in the Freedom of Information Act (FOIA) and how it may affect your community's planning process.

Subsidence

The Michigan Hazard Analysis (EMD-PUB 103) contains some useful introductory information but a detailed local analysis would need to obtain local information sources that MSP-EMD has not yet been able to access. Ideally, information about the locations and subsurface conditions of all mines in an area would be found, and testing or inspection could then determine their stability and safety. MSP-EMD has learned of valuable information that was collected on this topic through an academic research process, and has requested but not yet obtained access to this information. If you believe that subsidence is one of your area's significant hazards, please inquire with MSP-EMD to see if data has been obtained or whether some of it is considered confidential. You may call Mike Sobocinski at (517) 336-2053 for more information, or send a message to sobocinm@michigan.gov.

Thunderstorm Hazards

Thunderstorms are hazards that bring a variety of problems during the spring, summer, and fall seasons throughout the United States, and Michigan is no exception. Thunderstorms are meteorological phenomena that result from the clashing of warm and cold air masses, or during afternoons with unstable atmospheric conditions. Thunderstorms can bring potential lightning, flash flooding, and hail risks, while severe thunderstorms can produce large hail, extremely strong winds, and even tornadoes. Detailed information will be provided for hail, lightning, strong winds, and tornadoes following this general overview of thunderstorms.

In terms of the risk of thunderstorm occurrence for Michigan, there are three general categories of thunderstorm occurrence for the state. Prediction of occurrences is measured in the number of days during a year that have thunderstorm activity. The greatest annual risk for thunderstorms is seen in the two southernmost tiers of counties in the state (those counties along and south of I-94). These counties experience 40-60 "thunderstorm days" per year. The rest of the Lower Peninsula experiences 30-40 thunderstorm days per year, and the counties in the Upper Peninsula have the lowest total of thunderstorm days, at 20-30 per year.

One positive aspect of assessing thunderstorm risks comes from the fact that thunderstorm hazards have some degree of predictability and are closely monitored by the National Weather Service. In addition to daily forecasts, which predict the probability of possible rainy or stormy weather, the NWS system of Watches and Warnings help communities understand when there are potential risks of severe thunderstorms, or if the severe thunderstorms are imminently present. When the NWS issues a "Severe Thunderstorm Watch", that implies that thunderstorms with large hail and damaging winds are possible in your area. When the NWS issues a "Severe Thunderstorm Warning," it signifies that severe thunderstorms (with the damaging winds and hail) are in your area or will be imminently present.

The NWS has four offices in Michigan that are responsible for monitoring and providing predictions and bulletins for the entire state. The four offices are in Grand Rapids, Detroit, Gaylord, and Marquette. These stations provide information on severe weather watches and warnings, but also provide useful Doppler Radar images that track the movement of thunderstorms in your area. The Grand Rapids station covers the southwest portion of the state (www.crh.noaa.gov/grr); the Detroit station covers Southeast Michigan (www.crh.noaa.gov/dtx); the Gaylord station has coverage of the north central portion of the Lower Peninsula and the eastern edge of the Upper Peninsula (www.crh.noaa.gov/apx); and the Marquette station examines the majority of the Upper Peninsula (www.crh.noaa.gov/mqt).

Since thunderstorms bring the potential for dangerous hail, lightning, straight-line winds, and tornadoes, it is necessary to further examine each of those hazards. **Useful historical information on hail, severe winds, lightning, and tornadoes for your county can be found through the National Climatic Data Center's Storm Data website at http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms**. Data for each county in the state is listed here, and has historical records of significant events up to July, 2002 for hail (from 1968 for most counties); lightning (from 1993); severe winds (from 1960); and tornadoes (from 1950).

Thunderstorm Hazards: Hail
Hail is produced by thunderstorms when significant updrafts among the clouds allow for the growth of ice pellets which then fall with the heavy rains. Hail can be especially damaging to crops, home roofs, and automobiles. Approximately $1 billion in damages occurs annually across the United States. In Michigan, there is usually at least one intense hailstorm per year causing significant damages. Notably, in 2000, severe storms produced $4.1 million in hail damage to property in Iron and Dickinson Counties. Unfortunately, for many hailstorms, the total damages to property go unreported.

Structurally, there are few ways to mitigate against hail damage. New homes and businesses can be equipped with impact resistant roofing materials, and window shutters can be used. Insurance policies for homes, automobiles, and crops can be taken out to lessen economic impacts. A simple, inexpensive technique involves closely monitoring the National Weather Service when severe weather approaches to help inform the public of possible hail. Public information can help citizens move vehicles into garages and other covered areas.

To try to estimate the likelihood of a severe hailstorm in your county, the information about thunderstorm days (listed on the previous page) can provide a good starting point. In taking into consideration the 20-30 / 30-40 / 40-60 ranges of thunderstorm days for the state, these categories can be considered the maximum number of hail events that your area will experience per year. Thus, once you have estimated your community's overall risks of experiencing thunderstorm events, the risk of hail events will be somewhat lesser still, since not all thunderstorms produce damaging hail. Ideally, some estimate can be made from historic data of the percentage of thunderstorms that do produce damaging hail. There is no fixed percentage that can be applied statewide, as the incidence of hail is most likely for severe thunderstorms that also produce great amounts of precipitation, but the southern portion of the state will be more likely to experience these conditions than the northern parts.

Thunderstorm Hazards: Lightning
Lightning is an unpredictable phenomenon associated with thunderstorms that occurs 100 times each second globally. Lightning can be as hot as 50,000°F, and can cause damage to buildings, trees, and other structures. Damage from lightning strikes has been estimated by the National Lightning Safety Institute to be $5 billion annually. Lightning can be especially damaging on electrical infrastructure, causing localized power outages, and damage to phone lines and communication systems. Computers are also especially vulnerable to lightning strikes.

Lightning is a very dangerous hazard for people, as well. Lightning strikes kill and injure more people each year than tornadoes and hurricanes in the United States. Michigan ranks 2nd in the country (behind Florida) in lightning casualties (the combination of lightning deaths and injuries), with 99 deaths and 693 injuries from 1959 to July 2001.

In terms of lightning risk around the state, Southwestern Michigan has the highest rate of lightning strikes, according to Global Atmospherics, Inc., with a strike ratio of 4.0 flashes/km²/yr. Locations south of Midland have strike ratios of 3.0 flashes/km²/yr, and areas north of Midland have strike ratios of 2.0 flashes/km²/yr, including the Upper Peninsula.

Since lightning is an isolated phenomenon that causes great damage to a limited area and minimal damage to the structures adjacent to the lightning strike, it is necessary to determine lightning risks for some of the important buildings in your community. This is needed aside from the general risk assessment of lightning strikes per year for a given county in the state. One way to calculate the risk of lightning strikes for a type of structure in your area is by using an on-line "Lightning Risk Calculator" from HLP Systems, Inc. at http://www.apltd.com/cgi-local/aestiva/start.cgi/riskhlp.htm. This lightning calculator examines the risk associated with various types of building sizes, materials, heights, uses, and roof types. It is not a foolproof source for assessing lightning risks for buildings in your community, but it does provide a simple way to begin to look at how some areas may be affected by lightning strikes.

Thunderstorm Hazards: Severe Winds
Severe winds, or straight-line winds, that sometimes occur during severe thunderstorms can be very damaging to communities. Often, when straight-line winds occur, the presence of the forceful winds, with velocities over 58 mph, the wind event is confused with a tornado incidence. Severe winds have the potential to cause loss of life from property damage and flying debris, but do not produce as many deaths as tornadoes. However, the

property damage from straight line winds can be just as extreme as that of a tornado, since the damage from straight line winds is more widespread and usually affects multiple counties when they occur. In addition to property damage to buildings (especially less sturdy structures such as storage sheds, outbuildings, etc.), there is a risk for infrastructure damage from downed power lines from falling limbs and trees. Large scale power failures, with hundreds of thousands of customers affected, are common during straight-line wind events.

Another dangerous facet of straight line winds is that they occur more frequently beyond the April to September time frame that is seen with the other thunderstorm hazards. It is not rare to see severe winds ravage parts of the state in October and November. Stark temperature contrasts seen in colliding air masses along swift-moving cold fronts occur regularly during those months. Recently, there was a particularly damaging storm in late October 2001, as straight-line winds led to extensive damage in Berrien, Cass, Van Buren, Oakland, and Ingham Counties and led to a State-declared disaster in Kalamazoo County.

Since damaging straight-line winds are more widespread and have the propensity to occur outside of the traditional thunderstorm time frame of the year (April to Sept), this hazard may be more likely to cause damage to your community than hail or tornadoes. Additionally, straight-line winds have a much greater chance of occurring in southern Michigan than in northern Michigan. According to the National Severe Storms Laboratory, areas southeast and southwest of Lansing have 14-16 days with possible straight-line winds while areas north of Petoskey only have 0-2 days annually with straight-line wind potential. Between the two cities, the risk for straight-line winds diminishes evenly (if Lansing is used as the reference point). See http://www.nssl.noaa.gov/ for the map of this information.

Thunderstorm Hazards: Tornadoes

Tornadoes are high-profile hazards that can cause catastrophic damage to a limited or extensive area. Tornadoes are rapidly rotating columns of air that form most often in the spring and early summer months during some severe thunderstorms. A tornado can have winds in excess of 300 miles per hour and have widths over one mile. The deaths and injuries associated with tornadoes have declined since the 1950s thanks to advances in severe weather forecasting and technology improvements, but tornadoes can still be deadly killers. While tornado deaths have decreased, tornado damages have increased in recent years, with more and more outlying housing developments being constructed in previous farmland areas.

In the same fashion as severe winds, but with more extensive damage, there can be a wide swath of a community that can be completely destroyed by a tornado. Neighborhoods can be reduced to piles of splintered trees and homes, and a junkyard of twisted metal objects. One only has to think back to the Oklahoma City tornado outbreak of May 3, 1999 to see how a strong tornado can level everything in its path. Communities need to be aware of the risk of having a bevy of residents without homes, an area with no power or phone lines, a threat of bursting pipes, and a gigantic amount of scattered wooden and metallic debris to clean up.

In Michigan, tornadic activity is a real possibility, even if the state's tornado frequency pales in comparison with Oklahoma or Texas. There have been 954 tornadoes reported since 1950. There have been 239 related deaths, but only 12 since 1980, and none in the last five years. Although there haven't been any recent deaths, and few injuries, property damages have been very heavy, though inconsistent. According to the National Climatic Data Center, tornadoes in 2001 alone caused $28 million in property damage and $490,000 in crop damages in the state, while combined tornadoes in 1999 and 2000 only produced $2.4 million in property damage around the state.

The geographic risk for tornadoes in Michigan is far greater in the southern half of the state compared with the northern half. All counties south of Kent and Genesee Counties have had at least 12 tornadoes touch down in their boundaries from 1950-2001 (with the exception of St. Joseph County, having only 7 tornadoes). Genesee (36), Lenawee (30), and Kent (29) Counties have had the highest total of tornadoes in the state. North of Flint and Grand Rapids, only Saginaw County has had a relatively high total of tornadoes, with 16. The extreme northern portion of the Lower Peninsula and the Upper Peninsula overall have a lower risk of tornadoes, with all counties having 9 or fewer tornadoes over the 52-year time span.

To plan for tornadoes, counties should look at first to their historical data to determine a frequency of tornadoes over a time period. On the high end, Genesee County has a frequency of .692 tornadoes per year since 1950.

On the low end, Lake, Houghton, and Keweenaw Counties have frequencies of .019 tornadoes per year since 1950. This is an elementary way to begin analyzing tornado risks.

An advanced but related way for your community to analyze the tornado risk for various structures in your part of the state would be to employ the use of FEMA's 2000 computer model, "Benefit Cost Analysis of Hazard Mitigation Projects: Tornado and Hurricane Shelter Model." This program takes into consideration building information in terms of area, length, width, and location in the state to determine whether or not a mitigation project involving reinforced "safe rooms" will provide adequate protection during a tornado for building occupants. Although this program does not specify exact risk of tornado damage for each community, it does provide a crude regional model to follow for communities considering building tornado "safe rooms" to mitigate against tornado deaths and injuries. If your community wants to know more about the feasibility of the "safe rooms," the model is available through the MSP/EMD office.

Important Note: Only counties with significant tornado risks should inquire about the FEMA computer model, as the model does not work well for counties with very few tornado occurrences. Additionally, FEMA provides a disclaimer on the model that states that the results from the benefit-cost analysis are not conclusive or perfectly cost-effective—and that modeled projects are NOT guaranteed for potential government grants.

Major Transportation Accidents: Air, Land or Water

Useful sources of information are given in the hazard identification section of this workbook. Your community should first establish what level of transportation accident could create a community emergency or disaster event (as opposed to a traffic incident that only involves a couple of small vehicles). An example was given at the beginning of this section, in which a plane crash scenario was assessed. In a similar fashion, a train derailment scenario could be analyzed, or a passenger ferry incident, or a school or passenger bus crash. An event that might go almost unnoticed in a large and wealthy metropolitan area might easily overwhelm the resources of a poor and rural community. For example, a bus crash may cause all of a community's Emergency Medical Service resources to be used, leaving the community temporarily much more vulnerable, even to medical incidents that normally might be considered routine. Your assessment should determine what means of mass transit are available, how frequently a serious incident might be expected, who would be affected by it, and to what extent. Plane crash concerns may already have been analyzed by your area's airports or planners, such as in accordance with the Airport Zoning Act of 1950: (see http://www.michiganlegislature.org/documents/mcl/pdf/mcl-act-23-of-1950-ex-sess..pdf).

Severe Winter Weather Hazards

Winter storm hazards plague Michigan annually during November to March, with the state being vulnerable to snowstorms and ice and sleet storms. No area of the state is immune to severe wintry conditions that paralyze the transportation network, cause widespread power outages, and slow normal daily activities to a standstill. Each community should be prepared for the harsh landscape created by snow and ice extremes. One way to understand the approaching risks of winter weather comes in the form of daily forecasts, and winter watches and warnings from the National Weather Service. The website for the NWS is www.crh.noaa.gov, with access to whichever Michigan region in which your county is located.

To obtain recent county-level historical data from 1993-2002 for both severe snowstorms and ice and sleet storms, visit the National Climatic Data Center's Storm Event website, http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms and get a profile of your county's major winter storm history over the past 10 years. The site has one category for severe "Snow and Ice" storms, but categorizes them separately once a particular county's information is accessed.

The following two sections will outline the risks for ice, sleet, and snowstorms.

Severe Winter Weather Hazards: Ice and Sleet Storms

This category of winter storms is combined here, even though ice storms and sleet storms are two different phenomena. Ice storms, also known as freezing rain, coat roads, trees, power lines, and buildings with thick, heavy, and slick surfaces. Massive traffic accidents and power outages from downed tree limbs and utility lines are common when an ice storm occurs. Ice storms usually have a regional effect and may influence all corners of Michigan. Groups of counties are affected instead of just one county. Often times, ice storms are accompanied by snowfall, in which the ice is camouflaged and covered up by snow, creating treacherous transportation conditions. Sleet storms, which involve small pellets of ice accumulating on surfaces, are less dangerous than ice storms, but still cause potential harm to transportation and electrical systems. Both storms occur when the temperature is close to 32°F.

MSP-EMD staff has not yet found specific documentation on sleet and ice storms in the state to determine which parts of the state are more susceptible to them than others. The southern parts of the state have annual winter temperatures closer to 32°F, so the prevalence for ice and sleet storms seems more likely than in the northern areas of the state. Statewide, the period of occurrence of the ice and sleet is highest in January, February, and March.

Severe Winter Weather Hazards: Snowstorms

Snowstorms can be very dangerous for a community for short periods of time. Heavy snows can shut down towns and cities for a period of a few days if snow is persistent and cannot be cleared in a timely fashion. Pre-planning for snow storage areas will be helpful. Roof failures may occur as the weight of the snow and area of snow cause damage to homes and buildings. Motorists and passengers in cars can be stranded in rural areas and die of exposure because of inadequate preparation of conditions.

Extreme snowstorms can affect and temporarily disable any community in Michigan. A couple notable storms that crippled communities for a few days came during January 2-3, 1999 and January 26-27, 1977, buried cities and caused major havoc in the state. Lesser events are more likely on an annual basis.

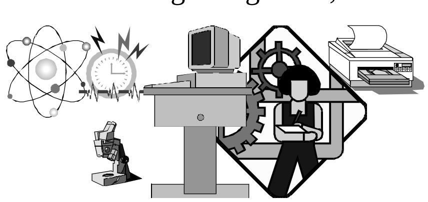
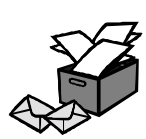
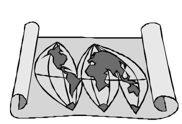
Extreme snows are most likely in the Upper Peninsula and the northern sections of Lower Michigan. Areas in the northwest portion of the Lower Peninsula average greater than 120 inches of snow annually west of Traverse City and near Gaylord. The snow is more extreme in the Upper Peninsula, as some areas of Baraga and Houghton Counties receive over 200 inches of snow per year. On the low end of snowfall totals, areas in the east central and southeastern portions of the state receive less than 50 inches of snow per year. Communities in West Michigan typically receive 60-100 inches of snow, because of the lake-effect snow.

Your community should assess its vulnerability to extreme snowfall events based on these risks and its ability to handle sudden influxes of snow. Urban areas are especially susceptible to outages and problems with snow removal, while rural areas may have inaccessible roads for some time but have residents that are more resilient to power outages and temporary isolation. Investigate how your community has handled past snow events to help determine the extent of its vulnerability and response capabilities.

Other hazards

You may find that there are local hazards you wish to include in your plan that were not explicitly dealt with in MSP-EMD guidance. This would be an expected part of local planning—that issues will be identified that previously had been invisible on the state level. The issue might be landslides (which might be treated as similar to erosion or flooding, based primarily on topographical data), fog (a special form of weather event that might be considered similar to severe weather), infestations (might affect agriculture or be treated as a public health emergency), muck fires (might be similar to wildfire events), or some form of local economic emergency (such as the effects of chronic wasting disease on a hunting community, or foot and mouth disease in a cattle-raising area). There might even be a concern with the possibility of cosmic impacts! Although planning for such a thing at the local level may be difficult, it might be treated as similar to local plans for a nuclear attack or terrorist event that might cause wide-scale destruction (see http://spacewatch.lpl.arizona.edu/arsw.html#V and http://www.csicop.org/si/9705/asteroid.html). Hopefully, this guidance book has given a good overview that can indicate how other hazards might be addressed, should you wish to include them in a local plan.

In some cases, MSP-EMD can be a useful source of information and advice. If you are analyzing your community's hazards and need assistance with finding data or processing it, feel free to inquire with Mike Sobocinski at (517) 336-2053 or sobocinm@michigan.gov. MSP-EMD is working on the creation of a GIS database for use in analyzing hazards, and as noted in various subsections of this appendix, may have useful information regarding dams, minelands, and hazard events that can be helpful in your analysis.


Section 2—Estimating Costs for Hazard Damages and Other Effects

A National Benefit-Cost Analysis Users Conference workshop was held in 2001, which included some extremely useful guidance materials about assessing, in economic terms, the various sorts of harm that a hazard might generate in a community. The guidance materials were called "What is a Benefit?" and apparently were created by URS Corporation in coordination with FEMA, but the materials don't seem to be very widely distributed beyond those who were at the conference to receive them. Key information from those materials is given here in this section, to assist in calculating estimated dollar values for many different types of hazard impacts. A "benefit" to a community can be seen in terms of losses that were avoided, due to successful hazard mitigation activities. Overall social benefits (public and private) are considered in these dollar amounts, not just those to a particular community or agency. Here is a list of the categories of benefits (avoided damages) found in this guidance source:

1. **Avoided Physical Damages** – Includes physical damages to buildings, the contents of buildings, infrastructure, landscaping, site contamination, vehicles, and equipment. If the replacement value of the structure or equipment is known, damages for many hazards can be estimated in terms of the percent of damage done to them, expressed in dollar terms as that percentage of the total replacement cost. (If something sustains damages greater than 50% of the total replacement cost, it is reasonable to estimate that the structure can be treated as a complete loss.) Such estimates apply to standard residential, commercial, or public buildings. More specialized facilities or historic sites will require the judgement of a professional assessor or engineer to estimate replacement costs.

   The costs to repair or replace structures and equipment are considered the potential physical damage costs of the hazard being analyzed. Such potential costs will then be multiplied by the probability of such a damaging event actually occurring at that site, and standardized into the "annual expected cost" figure described previously in this workbook. (See also the information previously provided under the Riverine and Urban Flood hazard section.)

2. **Avoided Losses of Function** – Includes "displacement" costs of temporary quarters when people are unable to use their normal residences or buildings because of a disaster, loss of rental income, loss of business income, loss of wage income, disruption time for residents, loss of public services, the economic impact of loss or interruption of utility services, and the economic impact of road and bridge closures.

   Displacement costs refer to the costs of obtaining temporary lodging or working space, in cases where damage is too extensive to allow the original building to continue being used. "Functional downtime" can also be calculated, by multiplying the duration of interrupted services by the economic value of those services (per unit of time). Loss of services can also be expressed in terms of percentages of lost services per unit of time (for example, two days with 50% loss of services). Ways to estimate these sorts of costs include finding prices for renting, preparing, and moving into temporary spaces with the needed furnishings and increased expenses of temporary provisions. Disruption time refers to time spent by residents in disaster response and recovery activities, using the principle that personal time has intrinsic value that is comparable to the amount one earns at work. Thus, the average value for wages could be used to represent such costs. Current wage information is available through the Michigan Department of Career Development at http://www.michlmi.org/.

   Loss of utility and public services can be valued according to the cost of providing those services, which can be estimated from their annual operating budgets. For services that are essential to disaster response and recovery, this value may be multiplied by an appropriate factor that reflects the greater importance of those services at the time of a disaster event. For example, if the annual budget for an Emergency Operations Center is $30,000 but it fully operates an average of only 3 days per year, each day's loss of use <u>during a disaster</u> might be estimated at a rate as high as $10,000 per day, until enough time passes that an alternative EOC can be put in place. In a non-critical period, EOC downtime costs are negligible.

   Critical utility services such as electric power, potable water, and wastewater processing are also generally much more valuable than their pricing would indicate, and their loss will tend to have larger economic impacts upon the functioning of the community. Estimates of reduced economic activity that may result from widespread loss of electric power has been calculated using national data, (producing an estimate of

$87 per day, per person working in the area) but this estimate should probably be adjusted for your specific region, based on NAICS data. In addition, the value of electric power for each residential customer is estimated at an average of $101 per day. Clearly, electric service is extremely important for our modern lifestyles. Its value for computer operation, lighting, communications, traffic control, cooking, industry, and medical services makes its provision critical to community function and public safety.

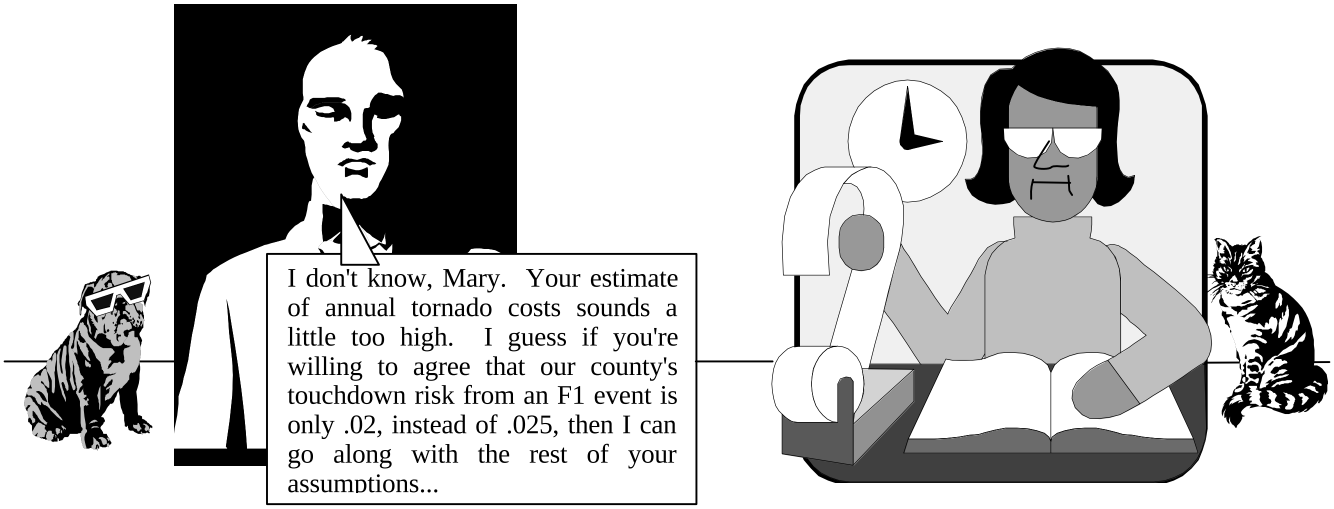
For lost wastewater service, reduced economic activity is estimated as $33.50 per person, per day (from national data, which should be adjusted to match your region's economic level using NAICS data) but would be only $8.50 per day if partial treatment of water is available. Loss of potable water can have a serious impact on public health, in addition to the inconvenience it causes. Its costs have been estimated at $68 per residential customer, plus $35 per person, per day for reduced regional economic activity.

Road and bridge closures also have an economic impact whose costs can be included in a detailed hazard analysis. The main impact of road closures is the loss of time, which can add up to substantial inefficiencies and economic costs as people try to travel and transport things, but cannot. A good starting point is to estimate the amount of time that a hazard reduces or prevents the flow of traffic along a stretch of roadway or across a bridge or tunnel. Traffic counts for that segment of the transportation system can then be researched or estimated using information from local or regional transportation planners (or possibly even web sources such as http://www.michigan.gov/mdot/0,1607,7-151-9622_11033_11149---,00.html). Estimated delay or detour times would then be calculated, and finally a cost per hour of delay would be applied. The standard value of each hour of a delayed vehicle, for FEMA benefit-cost analysis purposes, has been estimated as $32.23.

3. **Avoided Casualties** – Includes deaths, injuries, and illnesses suffered by persons during a disaster or emergency event. As mentioned in the section on Risk Assessment, there are suggested dollar amounts, based on statistical models, attached to minor injuries, major injuries, and deaths. In 2001, these values were estimated as $1,560 for each minor injury, $15,600 for each major injury, and $2,710,000 for each death. (For readers who are using this book years after these values were estimated, they can be adjusted to current economic values by using a cost-of-living adjustment such as available at http://www.jsc.nasa.gov/bu2/inflate.html. FEMA guidance cautions that casualties were found to be appropriate for modeling earthquakes, but may be much harder to defend in analyzing other, less catastrophic, types of hazards.

4. **Avoided Emergency Management Costs** – As described before, this includes the costs of activating and running an Emergency Operations Center, costs of evacuation and rescue operations, additional costs of security resulting from a disaster or emergency, costs of temporary sheltering and protective measures, costs of debris removal and cleanup, and costs of other disaster management activities.

The authors of this source material include in their book some comments that are worth quoting here: "...once the basic procedure for calculating benefits...is mastered, calculating additional benefits...is relatively straightforward....note that evaluating some types of projects, for example mitigation projects for utility systems, requires a moderate- to high-level of technical understanding of utility systems and thus should not be attempted by analysts lacking this expertise. Similarly, performing estimates of avoided casualty benefits...requires a considerable amount of experience and expertise and should not be attempted by novice analysts. Throughout the process of counting applicable benefits, care must also be taken to avoid double-counting benefits in more than one place or more than one subcategory." This appendix attempts to provide some information and methods that go beyond a subjective or intuitive understanding of a community's risks. In so doing, hopefully discussion of the tradeoffs of risks, costs, and benefits of mitigation actions can better be discussed in a community. Attempts to create a "risk model" with as many variables as possible will usually look impressive on paper. Since each variable contains some element of error, however, it is easy for a hypothetical risk model to compound such errors by combining variables before confirming (through further observations) that such variables truly interact in ways that the model assumes. Sometimes an intuitive understanding of risks can be just as accurate as elaborate equations, but the process of converting "intuition" into variables and measurements helps to *explain* the intuition to others in a way that can be helpful and clarifying to everyone! **The quantitative aspects of this appendix will not always make a risk analysis more valid, but they *can* make the analysis a more democratic and objective process, by helping to explain many abstract things to others in concrete ways.** These techniques of risk analysis can help convert "expert intuition" into a form that is understandable to others and can therefore assist a community with a decision-making process in which multiple stakeholders can participate and share their own experiences and insights. In cases of disagreement, these techniques can also help to produce compromises and consensus.



Costs and benefits that are secondary, or only hypothetically related to a disaster should probably not be counted, so as to make the hazard analysis a reliable and valid means of comparing hazard risks against each other and against other potential uses of hazard mitigation funds. For example, attempts to measure secondary job losses (stemming from reduced output in "base" industries) should not be included in a hazard analysis.

Linking your Hazard Analysis with Benefit-Cost Analysis

Once costs have been estimated, please remember that if you wish to actually apply them in a benefit-cost analysis, net benefits would be used, based on the difference between hazard costs under the status quo, and reduced hazard costs after a mitigation action is taken. Mitigation benefits will be gained only as long as the mitigation strategy is in place and effective at reducing hazard impacts. (This is why FEMA favors long-term or permanent solutions.) **A full benefit-cost analysis is not required, but enough information should be included to allow FEMA to estimate whether potential projects are likely to pass a benefit-cost analysis.**

Mitigation actions often have associated financial costs, and these must be compared to the benefits that will result from implementing them. Future benefits are being purchased with today's money, however. Since a dollar that is available today is more valuable than a dollar that is only available years in the future, future benefits are adjusted to allow them to be compared with today's dollars. This adjustment is called a discount rate, and the discount rate that FEMA recognizes is set at 7% per year. A mitigation benefit that is worth $1000 when it is realized a year from now, is today considered to be worth 7% less ($930). A mitigation benefit of $1000 that is realized only two years from now must be discounted by 7% in *each* of the two years that separates it from the present ($930 minus 7% is $864.90). Over long periods of time, the savings from each year can be added up when appropriately adjusted: if a project saves $1000 per year for the next 10 years, the total savings will appear at first to be $10,000, but when discounted to adjust for the present value of future dollars over the next ten years, it instead totals only $6,855.66 in terms of present-day dollar values. That is, $1000 will be counted as $930 (for next year's savings) + 864.90 (for the following year), and so on over the next ten years ($804.36 + $748.05 + $695.69 + $646.99 + $601.70 + $559.58 + $520.41 + $483.98 = $6,855.66) In effect, benefits that are more than a few decades away end up counting for very little in terms of today's dollars. Since each year's dollar is worth only 0.93 of a dollar in the preceding year, an amount of money X years in the future is worth only a fraction of the amount of the present year's dollar (more specifically, 0.93 raised to the power of X provides the fraction against which the dollar amount will be multiplied to convert it to its present-day value). Ten years' worth of savings (as shown above) totals only 68.6% of what it would before discounting. A thirty-year mitigation project saving $1,000 per year has a present value of only $12,410.

A 7% discount rate may sound high at first, but if we consider alternative ways a community may instead save or invest its money, the rate makes more sense. The effects of inflation (next year's dollar is not likely to buy as much as it can today), and the typical profits to be made on standard investments (which make dollars that are invested today worth more next year) provide reasons why a person or corporate entity might be reluctant to spend money today instead of investing it or delaying the expense another year.