ACME AMAZIUM REFINERY:
ALL HAZARDS PERFORMANCE PROFILE
(PARTICIPANT GUIDE)

Contents

1. Preface

1.1. Case Study Description

This case study is an exercise in writing an all-hazards performance profile for a fictitious facility in Memphis Tennessee using the Department of Homeland Security's Threat and Hazard Identification and Risk Assessment (THIRA) process (Department of Homeland Security, 2013) The introductory section offers a brief discussion of resilience and the elements of the all-hazards environment. Then, four task sections guide participants through the four-step THIRA process to:

Step 1: Identify the Threats and Hazards of Concern where participants list most of the possible hazards

Step 2: Give the Threats and Hazards Context where participants conduct detailed analysis of the most probable, critical, or significant hazards

Step 3: Establish Capability Targets where participants write system performance statements for these critical hazards

Step 4: Apply the Results where participants discuss how to achieve the desired facility performance in the all-hazards environment and some of the challenges of doing so.

References and links to appropriate websites are provided to guide the participants through the process. The case study concludes with a discussion on

1.2. Case Study objectives

1. Define the term 'all-hazards environment'.

2. Explain the effect of the all-hazards environment on system and facility design.

3. Given an infrastructure system, use the THIRA process to:

   - List the hazards that system might face selected the most important, most critical, and/or most likely ones.
   - Conduct a detailed assessment of critical hazards to determine the different levels of severity and probability of each.
   - Write a statement of performance for an infrastructure system for the dimensions of the all-hazards environment.

2. References

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3. Introduction

3.1. What is Resilience?

There are many answers which have evolved over time and address the concept from different perspectives. Some examples include:

- The Infrastructure Security Partnership (TISP): "the capacity to absorb or mitigate the impact of a hazard event while maintaining and restoring essential services (The Infrastructure Security Partnership, 2010)."
- Presidential Policy Directive 8 (PPD-8): the ability to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies (Obama, 2011).
- National Infrastructure Protection Plan: The ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions; includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents (Department of Homeland Security, 2013).

Which is 'right'? Well, all have something to tell us about the all-hazards environment and its relationship to resilience. The NIPP definition calls out elements of all-hazards environment while the TISP definition reminds us that we can respond differently to different types of events and that the focus of an infrastructure is to deliver an essential service. Sometimes we absorb the impact of an event and service continues uninterrupted; in other more extreme events services are interrupted and then restored. In this way we can say that we have designed for the 100 year event and are resilient in the 500 year event. To achieve this, we must articulate both the 100 and 500 year events and the performance of our structure in these events.

3.2. What is the All Hazards Environment?

In the NIPP, the All Hazards Environment "means a threat or an incident, natural or manmade, that warrants action to protect life, property, the environment, and public health or safety, and to minimize disruptions of government, social, or economic activities. It includes natural disasters, cyber incidents, industrial accidents, pandemics, acts of terrorism, sabotage, and destructive criminal activity targeting critical infrastructure (Department of Homeland Security, 2013)." For this case study we will organize the All Hazards Environment around four categories (Boone & Hart, 2013):

1. Natural Hazards. This broad categories includes independent events like floods (a flood this week does not change the likelihood of a larger flood next week) and dependent events like earthquakes (a large earthquake occurring today releases energy which decreases the likelihood of another event until the energy builds up again due to fault movement). These events are without intent.
2. Deliberate Malicious Acts. This term is not an attempt to be politically correct by avoiding the word 'terrorism', but rather is an attempt to include all possible threats like

terrorism, work place violence, disgruntled employee, industrial espionage, and protests[1]. It may be further divided into internal and external acts.

3. Accidents. Accidents are caused by people, and occasionally animals, through carelessness, inattention, fatigue, or ignorance but without malicious intent. These too may be further divided into internal and external accidents.

4. Deterioration. Deterioration is the degradation of infrastructure capacity over time as a result of exposure, wear, and use. This degradation tends to happen over a long time yet results in a failure which happens almost instantaneously like the failure of a 100 year old water line. The probability that something will fail due to deterioration tends to increase over time—think about a new car tire, the same tire with 40,000 miles on it, and that same tire with 72,347 miles.

Examples of threats and hazards in each of these categories can be found in both CPG 201 (Department of Homeland Security, 2013) and the Strategic National Risk Assessment (SNRA) (Department of Homeland Security, 2011). Some threat and hazard events areas can be determined probabilistically based on historical data or simulations such as flooding, earthquakes, tornados, some accidents, and some deterioration. Other events, like terrorism and workplace violence, are often so rare that there is no historical record so that a probability of occurrence cannot be determined. Add to this the fact that things come in different sizes ranging from the 10 year flood, to the 100 year flood, to the 500 year flood, to the "disaster of biblical proportions (Dr. Peter Venkman quoted by (Reitman, 1984))". The result is the need to articulate the All Hazards Environment in terms of multiple events with a hazard profile for each event. For example, a flood hazard profile for a riverside barge facility might look like:

Event	Level of Flooding relative to dock (- is below, + is above)	Probability of Occurrence in any given year	Cumulative probability over the 100 year life of the structure[2]	Cumulative probability if the structure lasts 200 years
10 Year Flood	-2 ft	10%	100%	100%
50 Year Flood	+1 ft	2%	87%	98%
100 Year Flood	+5 ft	1%	63%	87%
500 Year Flood	+12 ft	0.2%	18%	33%

Figure 1 Flood Hazard Profile

3.3. Linking Resilience to the All Hazards Environment

So how does the Flood Hazard Profile in Figure 1 relate to resilience? Go back to the definitions offered, or another one if preferred, and see that a resilient design allows us to absorb, without

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[1] Furthermore the terms 'man-caused disaster' or 'anthropogenic event' are insufficient because they fail to distinguish between deliberate and accidental acts. The distinction is not necessary for dealing with the impact, but is essential in designing protective and resilience measures.

[2] Cumulative probability is computed using the expression $1-(1-(1/T))^n$ with T being the return period and n being the number of years for the cumulative probability. In this case, T is the number of years in the event column and n is 100, the life of the structure. See http://en.wikipedia.org/wiki/Return_period and http://en.wikipedia.org/wiki/100-year_flood .

significant damage, the impacts of some events, and rapidly recover from the impact of others. Infrastructure owners, operators, and designers must decide which events to absorb and which to recover from (also how much recovery will have to be done in increasingly larger events). Based on the conditions shown in Figure 1, a resilient design strategy might appear as in Figure 2. Please note, this is an example only, which demonstrates that resilience requires a different approach to each event along the hazard profile, depending upon the infrastructure's criticality, risk tolerance, and financial position.

Event	Design Strategy
10 Year Flood	Ensure all offloading equipment can still reach barges with the barge waterline elevated to 2 ft below the dock. Elevate access roads to ensure no road is overtopped in the 10 year flood.
50 Year Flood	Construct dock of material that will not be damaged if submerged and will not become buoyant under 1 foot of water. Elevate all electrical and plumbing systems above the +1 ft level so they will not be damaged in the flood.
100 Year Flood	Construct dock of material that will not be *significantly* damaged if submerged and will not become buoyant under 5 foot of water. Non-structural damage (i.e. bumpers and fenders along the dock) is acceptable but structural damage is not. Remove all barges from the area and ensure no barge can crash into the docks. Since 24 hours warning of a flood along the river is usually available, design electrical, plumbing, and materials handling systems so that they can be secured from water damage for most components. Design all systems so that once the flood subsides, the docks can be placed back into operation in 72 hours.
500 Year Flood	The docks and the load handling equipment are our most expensive assets and take the most time to repair. Design the docks to withstand submersion of 12 ft. Remove all load handling equipment out of the area in preparation for the flood. Non-structural items, non-essential facilities, electrical systems, and plumbing systems will not be protected against this event.

Figure 2 Examples of Design Strategies for the Flood Hazard Profile

3.4. Conclusion

Traditional engineering design is binary—here is one design specification now design to that. For example, design a beam to support the loads in a standard office building. To the question, "What if the load is above that?" The designer will answer, "It fails." The designer will not articulate how it fails, exactly when it fails, the manner of the failure, or how easy it is to recover from the failure. Designing in the All Hazards Environment requires that architect, engineers, and owners consider the full range of events and how the facility will perform in each of these. No design code currently specifies this type of approach; it is up to the facility owner to request it of the planners, architects, and engineers.

This case study is an exercise in developing an All Hazards Profile for a fictitious facility. For the given scenario, participants will list most possible hazards, select the most probable or most damaging hazards, conduct a detailed investigation of these probable hazards to develop the

hazard profile, and conclude with formulating design strategies at each point along the profile. Don't worry, the last step is not an exercise in engineering design. Instead, it is a thought experiment in how an owner might expect the facility to perform in different adverse conditions. Architects and engineers can then propose designs to meet these performance conditions and the owner gets to decide if having that performance is really worth the cost.

Request for Proposals

ACME Enterprises announces the discovery of AMAZIUM, a new green energy fuel manufactured using natural gas and crushed limestone. When paired with new engine technologies, AMAZIUM will enable passenger cars to achieve an average of 80 miles per gallon at a retail fuel cost of $8 per gallon. Carbon emissions from an AMAZIUM engine are 30% of those from a gasoline or diesel engine. What's more, current fuel deliver systems (tankers, gas stations) can deliver AMAZIUM without any modifications.

ACME Enterprises is seeking proposals to design and build our new AMAZIUM refining facility in Memphis, TN. The facility will be bounded by Mario Street, Klinke Avenue, and the Mississippi River, See Figure 3 and Figure 4. The facility will include dock facilities on the river for the delivery of crushed limestone by barge and pipeline facilities to deliver the natural gas. The explosive risk of refining AMAZIUM is comparable to the refining of gasoline. Refining AMAZIUM produces one gallon of highly toxic solid waste per 250,000 gallons of motor vehicle fuel produced.

ACME Enterprises wants the AMAZIUM refinery to be the safest energy plant in the world. As AMAZIUM will fuel our nation for centuries to come, the design life of the facility is 200 years.

Selection of the design-build firm will be based on evaluation of Hazard-Performance Profiles submitted by candidate firms. Interested firms are asked to:

- Evaluate the All Hazards Environment for the proposed plant and list all (reasonably) potential hazards*
- Select the most critical hazards based on either probability of occurrence or severity of impact and develop and develop a hazard profile for each.
- Develop a performance profile for the critical hazards.

*Firms need not consider the Zombie Apocalypse, Godzilla, or the Stay Puft Marshmallow Man as these will be addressed by the ACME Enterprises Special Projects Division.

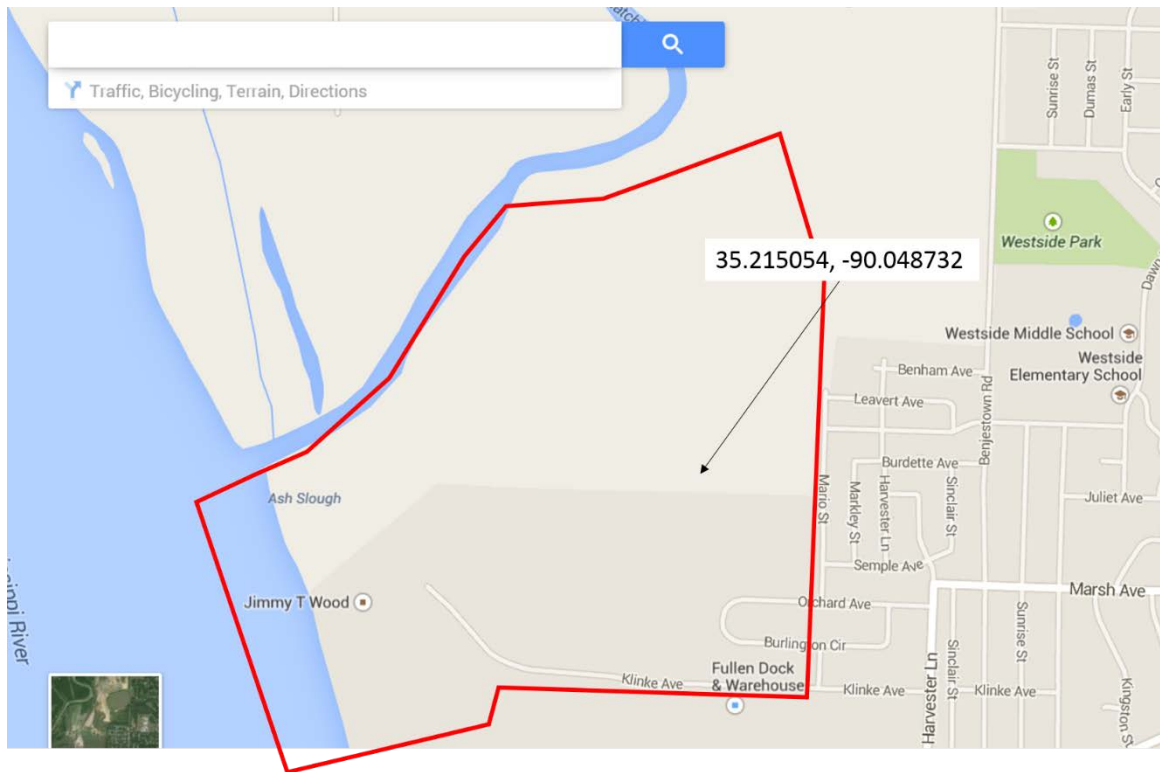## 4. Case Study Scenario

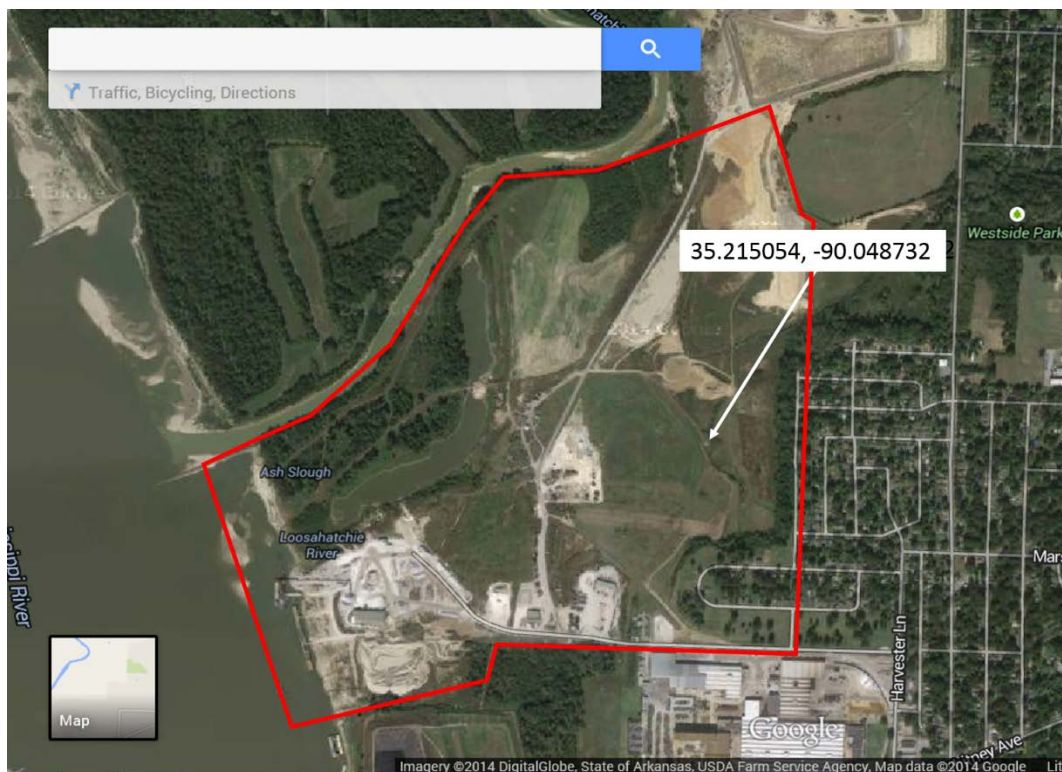Figure 3 ACME Amazium Refinery Location (Map)

Figure 4 ACME Amazium Refinery Location (Satellite)

5. Step 1: Identify the Threats and Hazards of Concern

In THIRA Step 1, communities or infrastructure facility owners define the threats and hazards of interest for the facilities in question, identify sources of threat and hazard information, and describe factors for including a specific event in Step 2. To begin the process of listing potential hazards, review the suggested lists in CPG 201 and the SNRA.

To begin this case study, complete the table in each section to list possible hazards to the ACME Amazium Refinery. Step 1 is a quick pass through all the things that might happen. Do not consider the likelihood of the event for the initial listing, simply brainstorm all the things that might happen. Use the references provided as well as internet searches to develop the list. When the list is complete, select the hazards for detailed analysis in Task 2. Hazards may be selected based on a high probability of occurrence, possibility for significant damage, or personal preference. For the purpose of the case study, the minimal hazards for Task 2 are already listed. Case study participant may select additional hazards for Task 2.

The case study is designed to take about three hours. To accomplish this, the class should divide up into four teams with each team taking on one of the four areas.

5.1. Natural Hazards

Generate a list of possible natural for the ACME Amazium Refinery. CPG 201 and the SNRA contains some examples as does an older FEMA publication: *Understanding Your Risks*, FEMA 386-2 (Federal Emergency Management Agency, 2001). Though FEMA 368-2 in no longer current (terminology and web links are out of date) it does contain useful suggestions on listing possible hazards and explanations of the hazards written in generally accessible terms.

Hazard or event description, (date of actual event if available)	Source of Information	Hazard Map Available?	Probable Event for Step 2
Earthquake			Yes
Floods			Yes
High Winds/Tornado			Yes

Figure 5 Possible Earth Effects and Natural Disasters

5.2.Deliberate Malicious Acts

Deliberate Malicious Act Example	Source of Information	Probable Event for Step 2
Ideological terrorism		Yes
Workplace violence/disgruntled employee		Yes
Environmental Protests		Yes

Figure 6 Possible Deliberate Malicious Acts

5.3.Accidents

Accident Example	Source of Information	Probable Event for Step 2
Accidental explosion		Yes
Loose barge on the Mississippi		Yes

Figure 7 Possible Accident Types

5.4.Deterioration

Accident Example	Source of Information	Probable Event for Step 2
Mean time to failure of mechanical parts		Yes
Metal Fatigue and deterioration in pipes		Yes

Figure 8 Possible Deterioration Types

6. Step 2: Give the Threats and Hazards Context

In Step 2, conduct a detailed assessment for the most likely or most critical hazards identified in Step 1. For Natural Hazards, appropriate websites and instructions are provided that assist in determining both level and probability of the hazard. For the other sections, conduct an internet search for relevant similar events and provide a description of the hazard faced by the ACME Amazium Refinery.

6.1.Natural Hazards

6.1.1. Earthquake

Engineers use peak ground acceleration as the basis for earthquake design, but these accelerations have little meaning to the general public. For this case study, we will use the more widely known description of earthquake intensity, magnitude. The magnitude of an earthquake is measured on the moment magnitude scale which sometime incorrectly referred to by the name of its predecessor, the Richter scale. Magnitudes are reported on a scale of 1 to 10. The scale is logarithmic meaning that an increase of 1 on the scale corresponds to a 10 fold increase in the recorded ground motions and a 32 fold increase in the amount of energy released. A magnitude 5 earthquake is a moderate earthquake and could be expected to cause slight damage to buildings, 6 is strong, 7 is major, and 8 is a great earthquake that could destroy buildings near the epicenter (Michigan Tech, 2014). (For a more technical description of earthquake magnitudes see (USGS, 2014)).

The probability that an earthquake of a given magnitude or larger will occur over the lifespan of a structure can be found using the US Geologic Survey's Earthquake Probability Mapping tool available at http://geohazards.usgs.gov/eqprob/2009/index.php . Simply input the location's latitude and longitude, the timespan to consider (i.e. the design life of the structure), and the minimum earthquake magnitude. Clicking the Compute Probability button return a map showing the probability that an earthquake of the given magnitude or larger will occur during the specified timespan. Note that on the map, the facility location is represented by a triangle at the center of the map. Use this tool to complete Figure 9.

Magnitude	Description	Cumulative Probability of this magnitude or higher in 200 year facility life
5	Moderate	
6	Strong	
7	Major	
8	Great	

Figure 9 Earthquake Probability

6.1.2. Flood

Flood levels are measured in terms of the expected return interval as shown in Figure 1 with longer return intervals corresponding to larger floods. Flood elevations are given on the Flood Insurance Rate Maps (FIRMs) published by FEMA and available at Map Service Center (https://msc.fema.gov/portal). The FIRMs will show the 100 and 500 year flood plains.

The website allows the complete FIRM panel to be printed or for a user to make a FIRMETTE, a small subsection of the FIRM panel for a given location. For this case study, retrieve the FIRM panel and make a FIRMETTE for the ACME Amazium Refinery. Determine which portions of the refinery are likely within which flood plains. The Map Service Center requires an address so use 3200 Mario Street, Memphis TN 38127. The FIRM is retrieve by downloading from this website. Click 'view' to see the FIRM and then print the FIRMETTE.

Record research and notes here:

Record assessment/conclusion here:

6.1.3. Tornado/High Winds

Use the FEMA Publication, Tornado Risks and Hazards in the Southeastern United States, (available at http://www.fema.gov/media-library-data/20130726-1604-20490-5503/2007_tornado_recoveries1.pdf) to assess the tornado risk for this facility.

Record research and notes here:

Record assessment/conclusion here:

6.2. Deliberate Malicious Acts

6.2.1. Terrorism

Research terrorist events toward similar facilities world-wide and formulate an assessment of the terrorist risk faced by the Amazium Refinery.

Record research and notes here:

Record assessment/conclusion here:

6.2.2. Work Place Violence

Research workplace violence that might occur at the Amazium Refinery. Focus on incidents that would disrupt refinery operations rather than those that are assault or harassment. Assault and harassment are, of course, critical issues for company operations, but are not a part of this exercise.

Record research and notes here:

Record assessment/conclusion here:

6.2.3. Protests

Research protests at similar institutions and formulate an assessment of the threats and hazards posed by protests to the Amazium Refinery.

Record research and notes here:

Record assessment/conclusion here:

6.3. Accidents

6.3.1. Loose Barge:

Research cases of loose barges or ships impacting bridge and dock piers and formulate an assessment of the risks of these events to the Amazium Refinery.

Record research and notes here:

Record assessment/conclusion here:

6.3.2. Accidental Explosion

Research accidental explosions in refineries and chemical plants and formulate an assessment of the risks of these events to the Amazium Refinery.

Record research and notes here:

Record assessment/conclusion here:

6.4. Deterioration

This area is particularly difficult because it is hard to find the right kind of information. Information tends to be available in the category of "The Part Broke" but not "And This Is The Bad Stuff That Happened When It Did." Much of the deterioration literature is focused on the failure and cause of the failure, not the impact of the failure or the recovery from it. Research the impact of deterioration on similar facilities and formulate a statement of the risks to the Amazium Refinery.

6.4.1. Mean Time to Failure of Mechanical Parts

For reference see the Wikipedia explanation for mean time to failure at:
http://en.wikipedia.org/wiki/Mean_time_between_failures

Record research and notes here:

Record assessment/conclusion here:

6.4.2. Deterioration of Metal Components

Research deterioration and corrosion as it relates to refining and chemical processes.

Record research and notes here:

Record assessment/conclusion here:

7. Step 3: Establish Capability Targets

Because this case study is focused on structure and facility performance, the capability targets are formulated performance statements for given hazards. These principle fall in the Prevention, Protection, and Mitigation mission areas, that when done well are intended to minimize the Response and Recovery mission areas. Even so, the performance targets also establish the start point for Response and Recovery.

In each section, tables are provided to guide responses. Participants should develop appropriate statements of performance for across the range of hazards. For Step 3, focus on how the facility should perform under duress, not how this performance can be achieved.

Instructor Information: Sample performance statements are included in the instructor version. "Supporting systems" means those not directly involved in AMAZIUM refining like human resources and public relations. 'System process' refers to the AMAZIUM refining process and those things immediately necessary to its operation.

The sample performance statements are meant to be illustrative, not definitive. They are not the 'approved solution.' One comment to be expected of participants is, "I don't know how to…" If participants get hung up on trying to write performance statements for a given area and are unable to do so, switch the question to, "Who do you need to bring to the table to help with this area?" See discussion suggestions below on building the team.

7.1. Earth Effects and Natural Disasters

7.1.1. Earthquake

Magnitude	Description	Probability of this magnitude or higher	Statement of System Performance
5	Moderate		
6	Strong		
7	Major		
8	Great		

7.1.2. Flood

Event	Design Strategy
10 Year Flood	
50 Year Flood	
100 Year Flood	
500 Year Flood	

7.1.3. Tornado/High Winds

Event	Statement of Performance
100 year wind event	
200 year wind event	
EF3-EF5 tornado	

7.2. Deliberate Malicious Acts

7.2.1. Terrorism

Event	Statement of Performance
Eco-, Industrial-, or ideological-terrorism	

7.2.2. Work Place Violence

Event	Statement of Performance
Worker on worker	
Industrial sabotage	

7.2.3. Protests

Event	Statement of Performance
Trespass for publicity	
Protests against operations	

7.3. Accidents

Event	Statement of Performance
Loose Barge	
Accidental	

explosion	

7.4.Deterioration

Event	Statement of Performance
Part failure	
Metal deterioration	

8. Step 4: Apply the Results

At this point, case study participants have listed most possible hazards, selected and researched the most critical, significant, or likely hazards, and drafted a statement of facility performance against those hazards. In this step of the THIRA, a community or infrastructure owners must allocated resources and develop plans to achieve the desired performance articulated in step 3. Conclude the case study with a discussion of how the leadership of the ACME Amazium Refinery would solicit, evaluate, and implement a resilient design program to achieve the desired performance in the all-hazards environment. Clearly this type of design approach will cost more than a traditional approach. How does the ACME leadership make the business case for a resilient design over a traditional design? In addition to a good design, what else is required for resilience?