ACME AMAZIUM REFINERY:
ALL HAZARDS PERFORMANCE PROFILE
(INSTRUCTOR 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

Boone, E. W., & Hart, S. D. (2013). Full Spectrum Resilience. *Homeland Security Review*.

Department of Homeland Security. (2009). *National Infrastructure Protection Plan.* Washington, D.C.: United States Government.

Department of Homeland Security. (2011). *Strategic National Risk Assessment In Support of PPD 8.* Washington DC: United States Government Printing Office.

Department of Homeland Security. (2013). *National Infrastructure Protection Plan.* Washington, D.C.: United States Government.

Department of Homeland Security. (2013). *Threat and Hazard Identification and Risk Assessment Guide: Comprehensive Preparedness Guide 201*. Washington D.C.: United States Government Printing Office.

Federal Emergency Management Agency. (2001). *Understanding Your Risks: Identifying Hazards and Estimating Losses (FEMA 386-2).* Washington DC: United States Government.

Michigan Tech. (2014, August 11). *How Are Earthquake Magnitudes Measured*. Retrieved from UPSEIS: http://www.geo.mtu.edu/UPSeis/intensity.html

Obama, B. (2011, March 30). Presidential Policy Directive 8: National Preparedness. Washington, D.C.: The White House.

Reitman, I. (Director). (1984). *Ghostbusters* [Motion Picture].

The Infrastructure Security Partnership. (2010). *White Paper for the White House Office of Critical Infrastructure Protection and Resilience Policy and Strategy.* Alexandria: The Infrastructure Security Partnership.

USGS. (2014, August 11). *Measuring the Size of an Earthquake*. Retrieved from Earthquake Hazards Program: http://earthquake.usgs.gov/learn/topics/measure.php

Instructor Guide Notes:

In this Instructor Version partial suggested 'answers' are indicated by the section header Instructor Information for text information and by blue highlights for instructor information in tables. This information does not appear in the participant guide and should not be provided to participants before the exercise. Additionally, instructors will find that they will collect insightful answers to questions each time the exercise is run. Recording these answers over time will result in a very detailed instructor solution.

Recommended timing for the case study:

Introduction and Case Study Scenario:	20 minutes
Step 1	20 minutes
Step 2	70 minutes
Step 3	50 minutes
Step 4	20 minutes

Additional materials provide for instructor:
Earthquake Hazards: Earthquake hazard probability maps from the USGS Website for magnitudes 5 to 8:

- M5 earthquake probability
- M6 earthquake probability
- M7 earthquake probability
- M8 earthquake probability
- USGS Earthquake Hazard Fact Sheet

Flood Hazards: Flood plain maps for case study

- FIRM Panel 47157C1260F
- CS2 Firmette
- CS2 Firmette legend

High Wind Hazards:

- Tornado Risks and Hazards in the Southeastern United States

Mean Time to Failures

- Mean time to failure in refinery pumps article
- Refinery MTTF Case History 3 Lyondell Citgo with figures

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

[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

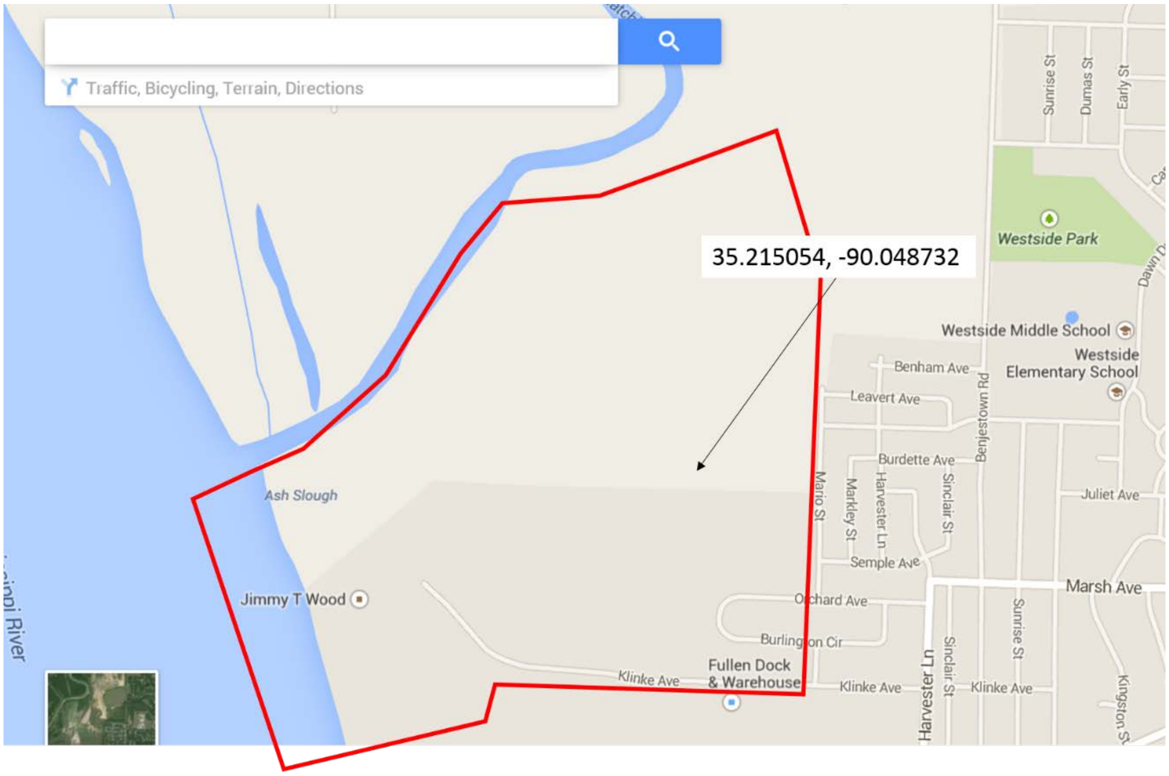

Figure 3 ACME Amazium Refinery Location (Map)

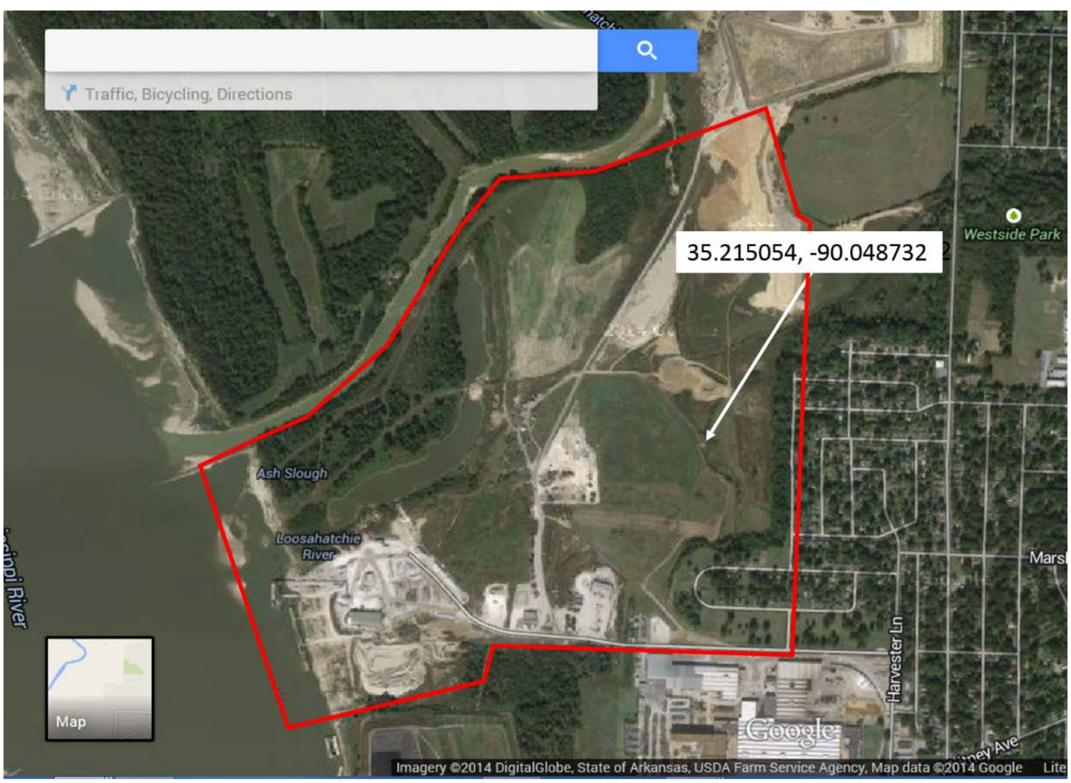

Figure 4 ACME Amazium Refinery Location (Satellite)

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	Yes
Floods		Yes	Yes
High Winds/Tornado		Yes	Yes
Wildfire		Yes	
Sinkholes/subsidence		Yes	
Extreme heat			
Hailstorm			
Severe Thunderstorm (lightning striking a steel facility full of explosive material!)			
Erosion of shorelines			
Silt deposit on facility during flooding			

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
Industrial terrorism		
Industrial espionage		
Workplace violence/disgruntled employee		Yes
Environmental Terrorism		
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
Release of chemicals (Bhopal India, Charleston West Virginia)		
Industrial accident injuring worker		
Leak of toxic byproducts		
Someone getting onto the site accidentally and getting hurt or disrupting process		
Vehicle accident on the facility		
Vehicle crashing into important parts of the refinery		
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
Rust and corrosion in structures		
Scour (underwater erosion) of piles on docks		

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 Hazrds, 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	25%
6	Strong	10%
7	Major	6%
8	Great	0%

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:

Instructor Information: The FIRM panel is 47157C0260F and a copy is provide in the instructor packet. The FIRMETTE is provide in PDF from with the approximate refinery locations shown. Portions of the refinery will be in the 100 year flood plan with a base flood elevation of 234 feet and portions will be in the 500 year flood plain. A second PDF is provided with the legend from the FIRM. Having the legend makes the FIRMETTE easier to understand. 10 and 50 year flood data is not available on this site.

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:

Instructor Information: According to the map on page 3, this area as 16-25 tornados per 3700 square miles and in in Wind Zone IV from page 4. This results in a High Risk of high wind events in the chart on page 3 and a recommendation for shelter as the preferred method of protection from high winds. The document goes on to show some techniques and standard for protecting facilities, or parts of facilities, from tornados and high wind events.

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:

Instructor Information:

Summary of eco-terrorism aimed at commercial meat industry: Chermak, Steven M., and Joshua Freilich, Celinet Duran, William S. Parkin. "An Overview of Bombing and Arson Attacks by Environmental and Animal Rights Extremists in the United States, 1995-2010," Final Report to the Resilient Systems Division, Science and Technology Directorate, U.S. Department of Homeland Security. College Park, MD: START, 2013. Available at: http://www.start.umd.edu/sites/default/files/files/publications/START_BombingAndArsonAttacksByEnvironmentalAndAnimalRightsExtremists_May2013.pdf

Articles on gas refinery attack in Algeria January 25, 2013:

http://www.domesticpreparedness.com/Infrastructure/Building_Protection/Gas_Refinery_Attack_in_Algeria:_The_Lessons_Learned/

http://en.wikipedia.org/wiki/In_Amenas_hostage_crisis

Assessment: An outright politically motivated terrorist attack on a refinery in the United States has not happened, but that does not mean it will not happen. More likely, based on past events, is an ecology motivated attack. One irony is that these attacks can release the very chemicals they are protesting against. Past history of ecological based attacks indicate they are carried out by individuals or small groups. A broader assessment of terrorist attacks in the west reveals they tend to be small groups rather than the larger ones seen in the Algerian attack referenced.

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:

Instructor Information:

Sample internet search results of work place violence related terms.

Employee on Employee violence (murder): http://www.jrrobertssecurity.com/case-001-floria.htm

Violence on College Campuses: http://www.nature.com/news/workplace-violence-caught-on-campus-1.14480

September 16, 2013, Navy Yard Shooting: http://www.defense.gov/pubs/DoD-Internal-Review-of-the-WNY-Shooting-20-Nov-2013.pdf

Industrial Sabotage: *FBI investigating alleged sabotage at Sinclair refinery in Wyoming* http://trib.com/business/energy/fbi-investigating-alleged-sabotage-at-sinclair-refinery-in-wyoming/article_049a15f3-bdd3-5d4b-aae0-a7920f2d8492.html

Assessment: Workplace violence is a real issue in the United States. Most shootings, assaults, and sabotage tend to be the action of one individual. In an industrial process such as this, there is a very really opportunity for one individual to impact the entire system by using the SCADA (supervisory, control, and data acquisition) systems.

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:

Instructor Information:

Samples of industrial protests at other facilities include:

East Bay Oil Refinery Protest Draws About 100 Demonstrators: http://www.eastbayexpress.com/SevenDays/archives/2014/05/19/east-bay-oil-refinery-protest-draws-about-100-demonstrators

210 Arrested at Chevron Refinery Protest: http://www.nbcbayarea.com/news/local/Dozens-Arrested-at-Chevron-Refinery-Protest-218240661.html

Ontario Activists Protest Tar Sands Pipeline By Locking Themselves to Machinery: http://www.youtube.com/watch?v=qK7ICUq3gXA

Oil train protesters arrested at Tesoro site: http://www.goanacortes.com/news/article_00cc7258-1680-11e4-8508-0019bb2963f4.html

Conclusion: While it unlikely in the United States that protesters would actively attempt to destroy elements of the facility, it is possible. What is more likely is that protestors would attempt to trespass on the facility, chain themselves to equipment or highly visible areas, and contact the press for publicity. Law enforcement may be required to remove them. The most likely impacts are disruption to operations and damage to facilities due to ignorance or carelessness. Because of the location of the refinery, both land based and water based protests must be considered.

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:

Instructor Information: Suggested websites for barge accidents on the Mississippi include:

May 23, 2013, *Oil spills into Mississippi River after barges break loose* http://www.stltoday.com/news/local/crime-and-courts/oil-spills-into-mississippi-river-after-barges-break-loose/article_ae1f5719-48d8-5527-82f8-072c1d944e5d.html

April 22, 2013, 114 barges break loose during flood, some strike bridge: http://www.usatoday.com/videos/news/nation/2013/04/22/2102703/

March 23, 2011, *Barges Break Loose, Hit Bridge on Mississippi River*: http://www.nola.com/traffic/index.ssf/2011/03/barges_break_loose_hit_bridge.html

July 22, 2014, Barge crashes into Port Canaveral Pier, causing $500K in damage. http://www.wesh.com/news/barge-crashes-into-port-canaveral-pier-causing-500k-in-damage/27094570#!bBj3pl

Conclusion: Designers must consider a loose barge, tug boat, or ship colliding with the unloading pier as a probable condition and design accordingly. From a resilience perspective, designers should consider both the impact to operations (loss of supply, loss of ability to bring in raw materials) and damage to the facilities.

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:

Instructor Information: Sample articles from internet search of ‘refinery explosion’:

March 23, 2005. Texas City Refinery Explosion. http://en.wikipedia.org/wiki/Texas_City_Refinery_explosion

April 2, 2010, Tesoro Refinery Fatal Explosion and Fire. http://www.csb.gov/tesoro-refinery-fatal-explosion-and-fire/

August 4, 2014, Fire at Norco Bio Diesel Plant. http://www.nola.com/traffic/index.ssf/2014/08/tank_fire_extinguished_at_st_c.html

September 19, 2013, PEMEX Refinery Explosion, Mexico. Video of the explosion: http://www.liveleak.com/view?i=5de_1366580083 . Second video: http://www.youtube.com/watch?v=Yn7Dun58-_Q . These are not news article but do show very well what a refinery explosion looks like.

The above links are to newspaper articles, television reports, and videos that show the effects of refinery explosions in general terms. For detailed reports on explosions, see the website of the

United States Chemical Safety Board (CSB) at www.csb.gov. The CSB is an independent government agency charged with investigating industrial chemical accidents. The website , contains investigations and reports, both completed and ongoing, for chemical accidents in the United States. For example, the report on the explosion at the Chevron Refinery in Richmond CA on August 6, 2012 is at http://www.csb.gov/chevron-refinery-fire/ . This page contains links to the report, recommendations, and a 8 minute video on the cause of the fire with an animation of how and why the fire occurred.

Conclusion: Accidental explosions must be considered a probable event. These can occur from human error as well as material deterioration, and often, a combination of the two. For this exercise on the Amazium Refinery, quantifying the levels or size of the explosion is difficult because explosion size depends upon explosive material present which depends upon process which has not yet been defined (or invented for that matter ☺). If the case study participants will be successful in this step if they reach the conclusions that:

a. A refinery explosion is a very real possibility, maybe even a probability

b. Explosions can vary in size and impact to the facility, the workers, and the community

c. We really need an expert to help us deal with this

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:

Instructor information:

An internet search on 'mean time to failure in refinery pumps' returns the journal paper *Weibull Analysis Of Time Between Failures Of Pumps Used In An Oil Refinery* that is included in the case study package.

Case Study on Mean Time to Failure in Refinery Systems available
http://www.reliability.com/industry/pdf/CaseHistory3_%20LyondellCitgo_wfigures.pdf

Conclusion: Parts break and bad stuff happens. At best there is a shutdown of the process which costs money but is repairable. At worst, there are injuries, deaths, damages to adjacent equipment and facilities, injury and impact to the neighborhood, and bad publicity.

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:

Instructor Information:

Newspaper article reporting that recent refinery explosions share a similar cause: sulfidation corrosion in pipes. This occurs when sulfur compounds in the pipe corrode the steel walls leading to thinner pipes which fail under pressure. Report: Severe pipeline corrosion caused massive Silver Eagle refinery explosion available at http://www.deseretnews.com/article/865600702/Report-Severe-pipeline-corrosion-caused-massive-Silver-Eagle-refinery-explosion.html?pg=all. Refer also to the Chevron Refinery Fire discussed in 6.3.2. This is an example of where deterioration causes a different hazard and effect.

Selecting Process Piping Materials available at: http://www.element.com/docs/technical-articles/technicalarticle_selectingprocesspipingmaterials.pdf

Instructor Note: There is surprisingly little information easily available on mean time to failure of pipes or how long a particular process takes to corrode a pipe. This would be very useful information in designing an inspection and repair/replacement program.

Conclusion: Pipes in the Amazium Refinery will corrode and failure to predict this corrosion will cause significant damages and operational and financial impacts. Determining when corrosion will occur, especially for a new process will be difficult but will be essential for the successful operation of the facility.

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	25%	Cosmetic damage like broken sheet rock and cracked windows is acceptable. No damage to refining process and supporting system components.
6	Strong	10%	No damage to refining system process. Repairable damage to supporting systems is acceptable. No leakage of dangerous chemical or hazardous waste.
7	Major	6%	No leakage of dangerous chemical or hazardous waste. Damage to system processes should be repairable in three days. Damage to supporting processes should be repairable in 14 days.
8	Great	0%	No leakage of dangerous chemical or hazardous waste. System processes will be repaired or replaced. Supporting process are expected to be destroyed.

7.1.2. Flood

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. All system processes will be protected against 100 year floods—no building in the flood plain.
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. Supporting systems may be built in the 500 year flood plain but critical process systems will not be.

7.1.3. Tornado/High Winds

Event	Statement of Performance
100 year wind event	No damage to system and supporting processes
200 year wind event	No damage to system process. Damage to supporting processes acceptable if it can be repaired in 5 days.
EF3-EF5 tornado	No deaths or injuries to plan personnel. No harmful leakage of chemicals or waste. Damage to system components repairable in 5 days. Supporting systems may be damaged beyond repair and have to be replaced.

7.2. Deliberate Malicious Acts

7.2.1. Terrorism

Event	Statement of Performance
Eco-, Industrial-, or ideological-	No access or damage to critical components of facilities. No access to hazardous waste processing. No leaking of chemicals or hazardous waste. Process disruption limited to two days.

terrorism	

7.2.2. Work Place Violence

Event	Statement of Performance
Worker on worker	No mass casualty events. No assaults or murders.
Industrial sabotage	No deliberate worker caused spills or releases of hazardous material. No loss of control processes.

7.2.3. Protests

Event	Statement of Performance
Trespass for publicity	No access or damage to critical components of facilities. No access to hazardous waste processing. No leaking of chemicals or hazardous waste
Protests against operations	Protests do not shut down production or distribution of product for more than 6 hours. No worker or delivery hurt or damaged by protests.

7.3. Accidents

Event	Statement of Performance
Loose Barge	Loose barges or drifting vessels cannot cause damage to piers and dock or disrupt loading/unloading operations for more than 12 hours.
Accidental explosion	Accidental explosion cannot cause damage or release of material beyond the plant boundaries. Accidental explosion cannot cause a cascading failure.

7.4. Deterioration

Event	Statement of Performance
Part failure	Failure of mechanical parts/systems does not cause system down time in excess of six hours.
Metal deterioration	No significant leaks and no injuries due to deterioration. System down time limited to six hours for a deterioration event. Monitoring program in place to detect and repair deteriorating components prior to failure.

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?

Instructor Information:

Clearly, there will be very limited time available for this discussion, but steps 1 through 3 are the focus of the case study. Once the performance goals are articulated, they can be achieved if sufficient leadership, design, and funding are applied.

Some interesting discussion questions or points include:

- How much time would it really take to do this?
- One function of leadership is to assemble the correct team members to tackle a problem. For this problem:
  - Who do we really need in the team to accomplish these tasks well?
  - How does the composition of the team need to change as we progress from Task 1 to the actual system design?
- How does management make decisions about the desired level of performance?
- How do we balance the desired level of performance with the financial realities of running a business?
- Could we really get a business or governmental entity to plan this way?