

Shale Gas Development
An Educational Module Using Three Case Studies and Three Scientific Concepts

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Instructors' Guide for Case Study 1: Correlation vs. Causation

OVERALL CASE STUDY GOALS

This teaching module contains three cases, along with instructional exercises and materials, to illustrate how scientific principles and processes are used to frame three basic concepts. The case studies are for use by undergraduate or graduate-level professional students in schools of business, public policy, journalism/communications, public health, and law. It is assumed that the students have little or no scientific or technical background. The three concepts that are based on the scientific approach are:

1. Correlation is not the same as causation.
2. Hazard is not the same as risk.
3. Risk assessment includes the evaluation of probability of occurrence and severity of negative consequences.

The topic used in this module to illustrate the application of scientific principles for analysis is the development of natural gas from shale deposits, or so-termed unconventional gas development.

In each of the three cases, a description of the circumstances surrounding the issue is framed, a selection of multimedia resources has been selected to demonstrate how using the concept can illuminate an understanding of the issue, and a structured exercise using the concept is provided to help students appreciate a real-world decision-making environment.

The three cases are all designed to use the same pedagogical approach and assessment to teach and evaluate learning outcomes. This guide is therefore applicable to all three cases.

GENERAL APPROACH AND OUTCOMES

The overall strategy is to use cases studies as a means of helping students to actively learn how to use techniques to address real-world problems. Problem-based learning using case studies encourages the development of critical thinking and problem-solving skills within the context of a real-world situation or set of circumstances. The case study process facilitates student interaction with both the resource materials and other students as they collaboratively compile and analyze information, and derive conclusions, based on using fundamental scientific principles. Part of the value of the process is learning how to interact with others in this overall process, a situation that will be repeated in the real world when nonscience decision makers will be interacting with technical experts and their scientific information.

Using the provided resources as documentation of the circumstances in the case, the students will be instructed to analyze the situation; explore the situation from the viewpoints of different stakeholders or actors in the case; determine what issues need to be considered in order to develop various possible courses of action; make an analysis; and based on the results,

provide recommendations for actions. Documentation of this process will be the basis for the learning assessment. Because of the limited time scheduled for these cases studies, the instructor will need to intervene and control the amount of student-initiated activities. The result is a project-/problem-based learning exercise.

Specific to this module, the students are expected to learn that there is an important and fundamental difference between circumstances and actions that spatially and temporally occur in proximity to an event and with what are the actions that cause the event.

Level

Graduate or advanced undergraduate college students in professional nonscience programs: law, public policy, business, journalism/communications, and public health.

Length

While these cases could be executed in a single approximately 1.25-hour class session (along with time required for advanced readings and assignment preparation), the activities could be enriched by extending the time to 1.5 hours or split into two or more class sessions.

CASE 1: CORRELATION IS NOT THE SAME AS CAUSATION – METHANE IN GROUNDWATER

Activities

1. Introduce the students to the all the resources available for the case study; will be used by groups in class and for the final question set. Assign selected resources ahead (2 hours required); require students to use information found in the resources to be able to frame the case by understanding what are perceived as problems by which stakeholders.
2. Stimulate thinking (15 minutes). Review *60 Minutes* clip that shows methane in groundwater.
3. Introduction (15 minutes). Form students into groups to:
 - a. Define the problem.
 - b. Describe the stakeholder groups (i.e., landowners, developers, regulators, and environmentalists).
 - c. Describe their perceptions of and positions on the problem.
 - d. Describe the types of information/evidence parties are using as the basis for their positions.
4. Guidance (5 minutes). Instructor speaks generally about particular scientific concept and makes minimal recommendations on how it could be applied in this case.
5. Group work (20 minutes). Students are broken into stakeholder groups and charged with recommending an approach to address the case study problem, using scientific methods.

- a. Must include some basic ideas about what data would be required, how it should be collected and analyzed, and what conclusions could be drawn.
 - b. May include aspects of uncertainty.

This can be done with data from the resources to try to address their questions as best as they can. This can either be an independent investigation or facilitated with predetermined sets of resources.
6. Reconvene (20 minutes). Groups report, receive feedback from each other on their recommendations. Teacher facilitates discussion across groups about their conclusions. Within this discussion, instructor helps them to clarify key terms related to correlation/causation.
7. Summary. Thoughts and guidance from instructor.
8. Follow up assignment. Set of questions that assess learning. Students use the background information, the class discussions, and the resource materials to answer questions with short, succinctly constructed responses of his/her conclusions and justifications.

Assessment

The learning outcomes for this case study can be assessed with a set of questions and the content of oral reports that the students present at the end of the class session. However, a postclass exercise on a different problem (selected by the instructor) is the most decisive method for determining whether the students understand the concept.

Grading

1. Oral presentation of the group will be graded based on:
 - a. Comprehensiveness of content.
 - b. Clarity of message.
 - c. Effectiveness of use of time and visuals.
2. Follow-up questions will be graded based on:
 - a. Correctness of response.
 - b. Clarity and efficiency of expression.

Resources

<http://en.wikipedia.org/wiki/Gasland>.

CBS *60 Minutes*: "Shale Gas Drilling: Pros & Cons," available at
<https://www.youtube.com/watch?v=UuGrawkuA2s>.

S.G. Osborn, A. Vengosh, N.R. Warner, and R.B. Jackson, "Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing," *Proc. Natl. Acad. Sci. USA* 108(20): 8172–8176 (2011).

D.I. Siegel et al., “Methane Concentrations in Water Wells Unrelated to Proximity to Existing Oil and Gas Wells in Northeastern Pennsylvania.” *Environ. Sci. Technol.* 49 (7): 4106–4112 (2015), available at <http://pubs.acs.org/doi/abs/10.1021/es505775c>.

Additional Example

Introduction of precautionary principle. Balance between what is documented and what is inferred. Possible “water contamination and health effects.”

U.S. Forest Service decision to allow UGD in George Washington NF:
See <http://www.washingtonian.com/blogs/capitalcomment/local-news/usda-forest-service-allows-fracking-threatening-washingtons-water-supply.php#.VG43KYlOgiY.email>.

Governor Cuomo decisions to ban UGD in New York:
New York State Department of Health, *A Public Health Review of High Volume Hydraulic Fracturing for Shale Gas Development* (2014).
Concerned Health Professionals of New York, *Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking (Unconventional Gas and Oil Extraction)* (2014).

Follow-up Assignment Questions

1. What is methane? How does methane come to be found in groundwater? When methane gets into groundwater, why is this a problem?
2. What phenomenon can be observed in the movie *Gasland*?
 - a. How do Osborne and colleagues justify linking the spatial correlation of methane in groundwater to modern shale gas production activities?
 - b. How did the scientists “fingerprint” the methane?
3. What could be wrong with their conclusions? Or what circumstances could cause their interpretations to be incorrect?
4. What do Siegel and colleagues conclude?
5. How could the different interrelations in these papers be used to address perceived problems? What practices or policies should be enacted based on the findings of these scientific studies?
6. What type of scientific study might reduce the degree of scientific uncertainty?
7. How should the existing uncertainty around the issue of the origin of methane in groundwater be incorporated into policies/practices?

Answers to Questions

1. The simplest of hydrocarbons, CH₄, gaseous in form at standard temperature and pressure. Normally, groundwater has extremely low or no levels of methane present. Stray or fugitive methane in groundwater is the presence of natural gas that has entered the groundwater from a human-made or natural source. Methane can

- enter a groundwater system by (1) human-made causes, including a leak from a gas pipeline or producing well, and by a fracture connecting a gas reservoir with the groundwater system; (2) natural causes, including natural fractures or other pathways for connecting a gas reservoir with a groundwater system, and by biological activity in the water generating methane within the groundwater system. It is a problem because it could be explosive in people's homes or buildings and could act as an asphyxiate if present in high concentrations.
2. Methane exsolving from tap water in concentrations high enough to be ignited.
 3. They sampled several water wells near to and away from oil and gas wells and used both the concentration of the methane and the isotopic composition of the gas to interpret that the methane concentrations near to gas wells was higher and that the methane found in the water wells had a thermogenic signature, making it sourced by leakage from a human-made connection between a deep source and the groundwater system.
 - a. Stable isotope signatures of carbon in the methane. Biological and thermogenic methane have distinctly different carbon isotopic fingerprints.
 - b. They only sampled several tens of wells. Statistical confidence is low. Other factors could be responsible for methane in groundwater, including seasonal variations due to changing hydrology, nonunique explanations for isotopic signatures, leaking distribution pipelines that serve the residences sampled, leaks from old oil and gas wells, and natural fractures supplying gas to the groundwater from deep sources.
 4. Based on more than 10,000 samples, there is no spatial correlation of elevated methane in groundwater and contemporary shale gas production.
 5. Osborne and colleagues' conclusions could be used as evidence that a human-made behavior is endangering health and safety, and therefore, gas production and distribution practices can be modified to ameliorate the problem. And as the problem near residences is a possible hazard, groundwater monitoring and remediation of leaks (gas well casing and pipelines) should be enacted.

Siegel and colleagues' conclusions could be used as evidence that there is no consistent connection between methane in groundwater and gas production/distribution. Therefore, no changes in human activities will change the problem. Groundwater monitoring could be used to detect the problem and alternative sources of water could be sought, or the direct problem could be mitigated (gas/water separation prior to water use).
 6. This appears to be an evolving problem with more data and less uncertainty being generated with the progress of time. Policy makers could "wait and see" how the circumstances play out. Or they could be more precautionary and require pre- and postdevelopment groundwater monitoring and reporting to detect hazards and take selected actions to reduce them. The challenge of who pays and how that expense is justified.

Students' Guide for Case Study 1: Correlation vs. Causation

OVERALL CASE STUDY GOALS

This teaching module contains three cases, along with instructional exercises and materials, to illustrate how scientific principles and processes are used to form three basic concepts. The three concepts that are based on the scientific approach are:

1. Correlation is not the same as causation.
2. Hazard is not the same as risk.
3. Risk assessment includes the evaluation of probability of occurrence and severity of negative consequences.

The topic used in this module to illustrate the application of scientific principles for analysis is the development of natural gas from shale deposits, or so-termed unconventional gas development.

In each of the three cases, a description of the circumstances surrounding the issue is framed, a selection of multimedia resources has been selected to demonstrate how using the concept can illuminate an understanding of the issue, and a structured exercise using the concept is provided to help students appreciate a real-world decision-making environment.

GENERAL APPROACH AND OUTCOMES

The overall strategy is to use case study analysis as a means to help you actively learn how using such techniques can be useful for addressing real-world problems. Problem-based learning using case studies encourages you to develop critical thinking and problem-solving skills within the context of a real-world situation or set of circumstances. The case study analysis process facilitates interaction with both the resource materials and other students as you collaboratively compile and analyze information, and derive conclusions, based on using fundamental principles. Part of the value of the process is learning how to interact with others in this overall process, a situation that will be repeated in the real world when nonscience decision makers will be interacting with technical experts and their scientific information.

Using the provided resources as documentation of the circumstances in the case, you will be instructed to analyze the situation; explore the situation from the viewpoints of different stakeholders or actors in the case; determine what issues need to be considered in order to develop various possible courses of action; make an analysis; and based on the results, provide recommendations for actions.

You will be assessed on how well you learn this process by two means:

1. The oral presentation of the recommendations of your group at the end of the class session.

2. Your responses to a set of questions that you will answer after class and turn in on a later date.

Specific to this module, you are expected to learn that there is an important and fundamental difference between circumstances and actions that spatially and temporally occur in proximity to an event and with what are the actions that cause of the event.

CASE 1: CORRELATION IS NOT THE SAME AS CAUSATION – METHANE IN GROUNDWATER

Activities

1. Before class:
 - a. Review all of the resources available for the case study; you will use these in groups in class and to answer the final question set (open book).
 - b. Read carefully the abstract and conclusions in Osborne and colleagues and Siegel and colleagues. Note the information in the diagrams, charts, and illustrations. Read the entire papers. Consider which stakeholders might find this information advantageous/disadvantageous.
2. In class, together watch *60 Minutes* piece (15 minutes). Who are the stakeholders in the world of shale gas development? What are their interests?
3. In class, introduction to topic (15 minutes). Form into groups to:
 - a. Define what is the problem based on various perspectives.
 - b. Describe the stakeholder groups.
 - c. Describe their perceptions of and positions on the problem.
 - d. Describe the types of information/evidence parties are using as the basis for their positions.
4. In class, guidance for analysis (5 minutes). Listen as instructor speaks generally about the scientific concept of assigning causality using scientific principles and makes some recommendations on how it could be applied in this case.
5. In class, group work (20 minutes). Break into stakeholder groups and discuss your concerns about methane in groundwater. Based on the scientific concept and associated principles, recommend an approach to address the problem. This is to be done with data from the resources to address the questions as well as possible.
 - a. Must include some basic ideas about what data would be required, how it should be collected and analyzed, and what conclusions could be drawn.
 - b. May include aspects of uncertainty
6. In class, reconvene (20 minutes). Groups report, receive feedback from each other on their recommendations.
7. In class, summary. Thoughts and guidance from instructor.
8. Follow up assignment. Answer set of questions using succinctly constructed responses based on what you have learned from the resources and class discussions.

Follow-up Assignment Questions

1. What is methane? How does methane come to be found in groundwater? When methane gets into groundwater, why is this a problem?
2. What phenomenon can be observed in the movie *Gasland*?
3. How do Osborne and colleagues justify linking the spatial correlation of methane in groundwater to modern shale gas production activities?
 - a. How did the scientists “fingerprint” the methane?
 - b. What could be wrong with their conclusions? Or what circumstances could cause their interpretations to be incorrect?
4. What do Siegel and colleagues conclude?
5. How could the two interrelations be used to address perceived problems? What practices or policies should be enacted based on the findings of these scientific studies?
6. How should the uncertainty around the issue of the origin of methane in groundwater be incorporated into policies/practices?

Grading

1. Oral presentation of the group will be graded based on:
 - a. Comprehensiveness of content.
 - b. Clarity of message.
 - c. Effectiveness of use of time and visuals.
2. Follow-up questions will be graded based on:
 - a. Correctness of response.
 - b. Clarity and efficiency of expression.

Resources

<http://en.wikipedia.org/wiki/Gasland>.

CBS *60 Minutes*, “Shale Gas Drilling: Pros & Cons,” available at

<https://www.youtube.com/watch?v=UuGrawkuA2s>.

S.G. Osborn, A. Vengosh, N.R. Warner, and R.B. Jackson, “Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing,” *Proc Natl. Acad. Sci. USA* 108(20): 8172–8176 (2011).

D.I. Siegel et al., “Methane Concentrations in Water Wells Unrelated to Proximity to Existing Oil and Gas Wells in Northeastern Pennsylvania,” *Environ. Sci. Technol.* 49(7): 4106–4112 (2015), available at <http://pubs.acs.org/doi/abs/10.1021/es505775c>.

Instructors' Guide for Case 2: Hazard vs. Risk

OVERALL CASE STUDY GOALS

This teaching module contains three cases, along with instructional exercises and materials, to illustrate how scientific principles and processes are used to frame three basic concepts. The case studies are for use by undergraduate or graduate-level professional students in schools of business, public policy, journalism/communications, public health, and law. It is assumed that the students have little or no scientific or technical background. The three concepts that are based on the scientific approach are:

1. Correlation is not the same as causation.
2. Hazard is not the same as risk.
3. Risk assessment includes the evaluation of probability of occurrence and severity of negative consequences.

The topic used in this module to illustrate the application of scientific principles for analysis is the development of natural gas from shale deposits, or so-termed unconventional gas development.

In each of the three cases, a description of the circumstances surrounding the issue is framed, a selection of multimedia resources has been selected to demonstrate how using the concept can illuminate an understanding of the issue, and a structured exercise using the concept is provided to help students appreciate a real-world decision-making environment.

The three cases are all designed to use the same pedagogical approach and assessment to teach and evaluate learning outcomes. This guide is therefore applicable to all three cases.

GENERAL APPROACH AND OUTCOMES

The overall strategy in using cases studies as a means to help students actively learn using techniques to address real-world problems. Problem-based learning using case studies encourages the development of critical thinking and problem-solving skills within the context of a real-world situation or set of circumstances. The process facilitates student interaction with both the resource materials and with other students as they collaboratively compile and analyze information, and derive conclusions. Part of the value of the process is learning how to interact with others in this overall process, a situation that will be repeated in the real world when nonscience decision makers will be interacting with technical experts and their scientific information.

Using the provided resources as documentation of the circumstances in the case, the students will be instructed to analyze the situation; explore the situation from the viewpoints of different stakeholders or actors in the case; determine what issues need to be considered in order to develop various possible courses of action; make an analysis; and based on the results,

provide recommendations for actions. Documentation of this process will be the basis for the learning assessment. Because of the limited time scheduled for these cases studies, the instructor will need to intervene and control the amount of student-initiated activities. The result is a project-/problem-based learning exercise.

Specific to this module, students are expected to learn that there is an important and fundamental difference between circumstances and actions that create a situation that could be dangerous to health and human welfare (hazard) and how a hazard becomes a risk based on the intensity or magnitude of the impact to humanity coupled with the probability that an event that creates the impact will occur (a risk).

Level

Graduate or advanced undergraduate college students in professional nonscience programs: law, public policy, business, journalism/communications, and public health.

Length

While these cases could be executed in a single approximately 1.25-hour class session (along with time required for advanced readings and assignment preparation), the activities could be enriched by extending the time to 1.5 hours or split into two or more class sessions.

CASE 2: HAZARD IS NOT THE SAME AS RISK

Activities

1. Introduce the students to all the resources available for the case study; will be used by groups in class and for the final question set. Assign selected resources ahead (2 hours required); require students to use information found in the resources to be able to frame the case by understanding what are perceived as problems by which stakeholders.
 - a. Suggested readings:
 - i. <https://fracfocus.org/chemical-use/what-chemicals-are-used>
 - ii. <http://energyindepth.org/national/doe-report-finds-no-evidence-of-hydraulic-fracturing-contaminating-water/>
 - iii. Reference on hazard and risk
2. Stimulate thinking (15 minutes). Review and discussion of “Danger of Fracking” website, US News and World report story, and recommendation letter in the New York State Department of Health report.
3. Introduction (15 minutes). Form students into groups to:
 - a. Define the problem from the various stakeholder perspectives.
 - b. Describe the stakeholder groups.
 - c. Describe their perceptions of and positions on the problem.

- d. Describe the types of information/evidence parties are using as the basis for their positions.
4. Guidance (5 minutes): Instructor speaks generally about particular scientific concept and makes minimal recommendations on how it could be applied in this case.
5. Group work (20 minutes): Students are broken into stakeholder groups and charged with recommending an approach to address the case study problem, using scientific methods.
 - a. Must include some basic ideas about what data would be required, how it should be collected and analyzed, and what conclusions could be drawn.
 - b. May include aspects of uncertainty.

This can be done with data from the resources to try to address their questions as best as they can. This can either be an independent investigation or facilitated with predetermined sets of resources.
6. Reconvene, (20 minutes). Groups report, receive feedback from each other on their recommendations. Teacher facilitates discussion across groups about their conclusions. Within this discussion instructor helps them to clarify key terms related to correlation/causation.
7. Summary. Thoughts and guidance from instructor.
8. Follow up assignment. Set of questions that assess learning. Students use the background information, the class discussions, and the resource materials to answer questions with short, succinctly constructed responses of his/her conclusions and justifications.

Assessment

The learning outcomes for this case study can be assessed with a set of questions during the discussion and by evaluating the content of oral reports that the students present at the end of the class session. However, a postclass exercise on a different problem (selected by the instructor) is the most decisive method for determining whether the students understand the concept.

Grading

1. Oral presentation of the group will be graded based on:
 - a. Comprehensiveness of content.
 - b. Clarity of message.
 - c. Effectiveness of use of time and visuals.
2. Follow-up questions will be graded based on:
 - a. Correctness of response.
 - b. Clarity and efficiency of expression.

Resources

<http://www.dangersoffracking.com/>.

<http://www.usnews.com/news/articles/2014/10/30/toxic-chemicals-and-carcinogens-skyrocket-near-fracking-sites-study-says>.

<http://geology.com/energy/hydraulic-fracturing-fluids/>.

<http://fracfocus.org/water-protection/drilling-usage>.

<https://fracfocus.org/chemical-use/what-chemicals-are-used>.

<http://www.exxonmobilperspectives.com/2011/08/25/fracking-fluid-disclosure-why-its-important-2/>.

<http://www.energytomorrow.org/blog/2013/may/study-no-groundwater-contamination-from-arkansas-fracking>.

<http://nicholas.duke.edu/news/new-tracers-can-identify-fracking-fluids-environment>.

N.R. Warner, T.H. Darrah, R.B. Jackson, R. Millot, W. Kloppmann, and A. Vengosh, "New Tracers Identify Hydraulic Fracturing Fluids and Accidental Releases from Oil and Gas Operations," *Environmental Science and Technology* (2014), DOI: 10.1021/es5032135. [es5032135](https://doi.org/10.1021/es5032135).

<http://pubs.usgs.gov/sir/2012/5273/>.

N.R. Warner, T.M. Kresse, P.D. Hays, A. Down, J.D. Karr, R.B. Jackson, and A. Vengosh, "Geochemical and isotopic variations in shallow groundwater in areas of Fayetteville Shale development, north central Arkansas," *Applied Geochemistry* 35: 207–220 (2013).

<http://energyindepth.org/national/doe-report-finds-no-evidence-of-hydraulic-fracturing-contaminating-water/>.

R. Hammack, W. Harbert, S. Sharma, B. Stewart, R. Capo, A. Wall, A. Wells, R. Diehl, D. Blaushild, J. Sams, and G. Veloski, *An Evaluation of Fracture Growth and Gas/Fluid Migration as Horizontal Marcellus Shale Gas Wells are Hydraulically Fractured in Greene County, Pennsylvania*, NETL-TRS-3-2014, EPA Technical Report Series, U.S. Department of Energy, National Energy Technology Laboratory: Pittsburgh, PA (2014): 76.

New York State Department of Health, *A Public Health Review of High Volume Hydraulic Fracturing for Shale Gas Development* (2014) 184 pp.

Follow-up Assignment Questions

1. What is a hazard? How is a phenomenon, substance, or practice determined to be hazardous?
2. What is a risk? What is the relationship of magnitude and probability of occurrence to risk?
3. What are the potential sources of human exposure (exposure pathways) of toxic chemicals associated with the practice of hydraulic stimulation?
4. What are the inferences being made by those that are linking hazards to risks in association with hydraulic stimulations?
5. What facts need to be investigated to determine if a hazard is actually a risk in this circumstance?
6. What is the credibility of the sources? What are their agendas?

Answers to Questions

1. A hazard is a circumstance that can cause harm to health, welfare, property, or the environment. A phenomenon, substance, or practice determined to be hazardous by empirical evidence that demonstrates harm caused by a physical, chemical, or situational circumstance. In health these can be epidemiological studies. In safety, workplace and home accident histories.
2. A risk is the coupling of a hazard with the probability that it will occur along with the degree or magnitude of the impact.
3. Pathways include: Water – surface: spilled chemicals leaked into water or accidental or purposeful discharge of makeup chemicals or produced fluids. Water – groundwater: percolation of contaminants from surface, leaking well casing, or fracture communication of reservoir to groundwater system. Air: dispersed chemicals could be in the air? Physical contact: workers, residents, or livestock could physically come in contact with chemicals.
4. That one or more of the above-cited pathways form contact is very effective, that is, enough materials are conveyed through time to present a hazard. The concentrations of the chemicals must be high enough and the exposure must be complete enough to pose threat to human health.
5. Are pathways in place? Do they convey concentrations of chemicals at high levels for significant amounts of time (repeats or constant vs. occasional)?
6. Some scientists may be credible, but they often have agendas. Insurance companies use actuarial information to assess risk and value protection costs. The same goes with public officials (e.g., New York state). Industry could be credible to preserve and enhance local (and other scales) perception to have social license to operate. Pro-business, pro-development interest may be highly suspect in objectivity, as could interest groups such as environmental activists.

Students' Guide for Case Study 2: Hazard vs. Risk

OVERALL CASE STUDY GOALS

This teaching module contains three cases, along with instructional exercises and materials, to illustrate how scientific principles and processes are used to frame three basic concepts. The three concepts that are based on the scientific approach are:

1. Correlation is not the same as causation.
2. Hazard is not the same as risk.
3. Risk assessment includes the evaluation of probability of occurrence and severity of negative consequences.

The topic used in this module to illustrate the application of scientific principles for analysis is the development of natural gas from shale deposits, or so-termed unconventional gas development.

In each of the three cases, a description of the circumstances surrounding the issue is framed, a selection of multimedia resources has been selected to demonstrate how using the concept can illuminate an understanding of the issue, and a structured exercise using the concept is provided to help students appreciate a real-world decision-making environment.

GENERAL APPROACH AND OUTCOMES

The overall strategy is to use case study analysis as a means to help you actively learn how using such techniques can be useful for addressing real-world problems. Problem-based learning using case studies encourages you to develop critical thinking and problem-solving skills within the context of a real-world situation or set of circumstances. The case study analysis process facilitates interaction with both the resource materials and other students as you collaboratively compile and analyze information, and derive conclusions, based on using fundamental principles. Part of the value of the process is learning how to interact with others in this overall process, a situation that will be repeated in the real world when nonscience decision makers will be interacting with technical experts and their scientific information.

Using the provided resources as documentation of the circumstances in the case, you will be instructed to analyze the situation; explore the situation from the viewpoints of different stakeholders or actors in the case; determine what issues need to be considered in order to develop various possible courses of action; make an analysis; and based on the results, provide recommendations for actions.

You will be assessed on how well you learn this process by two means:

1. The oral presentation of the recommendations of your group at the end of the class session.

2. Your responses to a set of questions that you will answer after class and turn in on a later date.

Specific to this module, you are expected to learn that there is an important and fundamental difference between circumstances and actions that create a situation that could be dangerous to health and human welfare (hazard) and how a hazard becomes a risk based on the intensity or magnitude of the impact to humanity coupled with the probability that an event that creates the impact will occur (a risk).

CASE 2: HAZARD IS NOT THE SAME AS RISK

Activities

1. Before class:
 - a. Review all of the resources available for the case study; you will use these in groups in class and to answer the final question set (open book).
 - b. Read carefully the abstract and conclusions in:
 - i. <https://fracfocus.org/chemical-use/what-chemicals-are-used>
 - ii. <http://energyindepth.org/national/doe-report-finds-no-evidence-of-hydraulic-fracturing-contaminating-water/>
 - iii. Reference on hazard and riskNote the information in the diagrams, charts, and illustrations. Read the entire papers. Consider which stakeholders might find this information advantageous/disadvantageous.
2. In class (15 minutes). Together, we will review and discuss the “Danger of Fracking” website, US News and World report story, and recommendation letter in the New York State Department of Health report. Consider, who are the stakeholders in the world of shale gas development? What are their interests?
3. In class, introduction (15 minutes). Form into groups to:
 - a. Define what the problem is from the various stakeholder perspectives.
 - b. Describe the stakeholder groups.
 - c. Describe their perceptions of and positions on the problem.
 - d. Describe the types of information/evidence parties are using as the basis for their positions.
4. In class, guidance (5 minutes). Listen as instructor speaks generally about the scientific concept of assigning causality using scientific principles and makes some recommendations on how it could be applied in this case.
5. Group work (20 minutes). Break into stakeholder groups and discuss your concerns about methane in groundwater. Based on the scientific concept and associated principles, recommend an approach to address the problem. This is to be done with data from the resources to address the questions as well as possible.
 - a. Must include some basic ideas about what data would be required, how it should be collected and analyzed, and what conclusions could be drawn.

- b. May include aspects of uncertainty.
- 6. In class, reconvene (20 minutes). Groups report, receive feedback from each other on their recommendations.
- 7. In class, summary. Thoughts and guidance from instructor.
- 8. Follow-up assignment. Answer a set of questions using succinctly constructed responses based on what you have learned from the resources and class discussions.

Follow-up Assignment Questions

1. What is a hazard? How is a phenomenon, substance, or practice determined to be hazardous?
2. What is a risk? How is it related to magnitude and probability of occurrence?
3. What are the potential sources of human exposure (exposure pathways) of toxic chemicals associated with the practice of hydraulic stimulation?
4. What are the inferences being made by those that are linking hazards to risks in association with hydraulic stimulations?
5. What facts need to be investigated to determine if a hazard is actually a risk in this circumstance?
6. What is the credibility of the sources? What are their agendas?

Grading

1. Oral presentation of the group will be graded based on:
 - a. Comprehensiveness of content.
 - b. Clarity of message.
 - c. Effectiveness of use of time and visuals.
2. Follow-up questions will be graded based on:
 - a. Correctness of response.
 - b. Clarity and efficiency of expression.

Resources

<http://www.dangersoffracking.com/>.
<http://www.usnews.com/news/articles/2014/10/30/toxic-chemicals-and-carcinogens-skyrocket-near-fracking-sites-study-says>.
<http://geology.com/energy/hydraulic-fracturing-fluids/>.
<http://fracfocus.org/water-protection/drilling-usage>.
<https://fracfocus.org/chemical-use/what-chemicals-are-used>.
<http://www.exxonmobilperspectives.com/2011/08/25/fracking-fluid-disclosure-why-its-important-2/>.
<http://www.energytomorrow.org/blog/2013/may/study-no-groundwater-contamination-from-arkansas-fracking>.
<http://nicholas.duke.edu/news/new-tracers-can-identify-fracking-fluids-environment>.

- N. R. Warner, T.H. Darrah, R.B. Jackson, R. Millot, W. Kloppmann, and A. Vengosh, *New Tracers Identify Hydraulic Fracturing Fluids and Accidental Releases from Oil and Gas Operations: Environmental Science and Technology* (2014), DOI: [10.1021/es5032135](https://doi.org/10.1021/es5032135).
<http://pubs.usgs.gov/sir/2012/5273/>.
- N.R. Warner, T.M. Kresse, P.D. Hays, A. Down, J.D. Karr, R.B. Jackson, and A. Vengosh, "Geochemical and isotopic variations in shallow groundwater in areas of Fayetteville Shale development, north central Arkansas," *Applied Geochemistry* 35: 207–220 (2013).
<http://energyindepth.org/national/doe-report-finds-no-evidence-of-hydraulic-fracturing-contaminating-water/>.
- R. Hammack, W. Harbert, S. Sharma, B. Stewart, R. Capo, A. Wall, A. Wells, R. Diehl, D. Blaushild, J. Sams, and G. Veloski, *An Evaluation of Fracture Growth and Gas/Fluid Migration as Horizontal Marcellus Shale Gas Wells are Hydraulically Fractured in Greene County, Pennsylvania*, NETL-TRS-3-2014, EPAAct Technical Report Series, U.S. Department of Energy, National Energy Technology Laboratory: Pittsburgh, PA (2014): 76.
- New York State Department of Health, *A Public Health Review of High Volume Hydraulic Fracturing for Shale Gas Development* (2014) 184 pp.

Instructors' Guide for Case Study 3: Risk Assessment

OVERALL CASE STUDY GOALS

This teaching module contains three cases, along with instructional exercises and materials, to illustrate how scientific principles and processes are used to frame three basic scientific concepts. The case studies are for use by undergraduate or graduate-level professional students in schools of business, public policy, journalism/communications, public health, and law. It is assumed that the students have little or no scientific or technical background. The three concepts, each drawn from different realms of science, are:

1. Correlation is not the same as causation.
2. Hazard is not the same as risk.
3. Risk assessment includes both the probability that an adverse event will occur and the severity of the adverse consequences.

The topic used in this module to motivate and illustrate the scientific concepts is the development of natural gas from shale deposits, or so-termed unconventional gas development. In the mass media, the activity is loosely referred to as “fracking.”

In each of the three cases, a description of the circumstances surrounding the issue is framed, a selection of multimedia resources has been selected to demonstrate how using the concept can illuminate an understanding of the issue, and a structured exercise using the concept is provided to help students appreciate a real-world decision-making environment.

The three cases each use the same pedagogical approach and assessment to teach and evaluate learning outcomes. This guide is therefore applicable to all three cases.

GENERAL APPROACH AND OUTCOMES

The overall strategy employs case studies to help students actively learn and apply scientific concepts when solving real-world problems. Such problem-based learning encourages the development of critical thinking and problem-solving skills within the context of a real-world situation or set of circumstances. The case study process facilitates student interaction with both the resource materials and with other students as they collaboratively compile and analyze information, and derive conclusions, based on the scientific concepts. Part of the value of the process is learning how to interact with others in this overall process, a situation that will be repeated in the real world when nonscience decision makers will be interacting with technical experts and their scientific information.

Using the provided resources as documentation of the circumstances in the case, the students will be instructed to analyze the situation; explore the situation from the viewpoints of different stakeholders or actors in the case; determine what issues need to be considered in order to develop various possible courses of action; make an analysis; and based on the results,

provide recommendations for actions. Documentation of this process will be the basis for the learning assessment. Because of the limited time scheduled for these cases studies, the instructor will need to intervene and control the amount of student-initiated activities. The result is a problem-based learning exercise.

Specific to this module, the students are expected to learn that there is an important process to undertaking a risk analysis. It contains an assessment of the hazard and couples that with factors that could be responsible for elevating the hazard into a risk. Additionally, establishing the degree of risk is a fundamental component of risk analysis.

Level

Graduate or advanced undergraduate college students in professional nonscience programs: law, public policy, business, journalism/communications, and public health.

Length

While the cases could be executed in a single approximately 1.25-hour class session (along with time required for advanced readings and assignment preparation), the activities could be enriched by extending the time to 1.5 hours or split into two or more class sessions per case study.

CASE 3: RISK ASSESSMENT

Activities

1. Introduce the students to all the resources available for the case study; will be used by groups in class and for a final question set. Assign selected resources ahead (Ellsworth, 2013; 2 hours required); require students to use information found in the resources to be able to frame the case by understanding what problems are perceived by various stakeholders.
2. Stimulate thinking (15 minutes). Review National Academy of Sciences YouTube video on induced seismicity.
3. Introduction (15 minutes). Form students into groups to:
 - a. Define the problem based on the video.
 - b. Describe the stakeholder groups (i.e., landowners, developers, regulators, and environmentalists).
 - c. Describe their perceptions of and positions on the problem.
 - d. Describe the types of information/evidence parties are using as the basis for their positions.
4. Guidance (5 minutes). Instructor speaks generally about particular scientific concept and makes minimal recommendations on how it could be applied in this case.

5. Group work (20 minutes). Students are broken into stakeholder groups and charged with recommending an approach to address the case study problem, using scientific concepts and modes of thinking.
 - a. Must include some basic ideas about what data would be required, how it should be collected and analyzed, and what conclusions could be drawn.
 - b. May include aspects of uncertainty.This can be done with data from the resources to try to address the questions as best as they can. This can either be an independent investigation or facilitated with predetermined sets of resources.
6. Reconvene (20 minutes). Group reports, receives feedback from each other on their recommendations. Teacher facilitates discussion across groups about their conclusions. Within this discussion, instructor helps them to clarify key terms related to correlation/causation.
7. Summary. Thoughts and guidance from instructor.
8. Follow-up assignment. Set of questions that assess learning. Students use the background information, the class discussions, and the resource materials to answer questions with short, succinctly constructed responses of his/her conclusions and justifications. The follow-up assignment will test the ability of students to distinguish correlation and causation in a different application setting.

Assessment

The learning outcomes for this case study can be assessed with a set of questions during the discussion and by evaluating the content of oral reports that the students present at the end of the class session. However, a postclass exercise on a different problem (selected by the instructor) is the most decisive method for determining whether the students understand the concept.

Grading

1. Oral presentation of the group will be graded based on:
 - a. Comprehensiveness of content.
 - b. Clarity of message.
 - c. Effectiveness of use of time and visuals.
2. Follow-up questions will be graded based on:
 - a. Correctness of response.
 - b. Clarity and efficiency of expression.

Resources

M.D. Petersen et al., *Incorporating Induced Seismicity in the 2014 United States National Seismic Hazard Model—Results of 2014 Workshop and Sensitivity Studies*, Open-File Report 2015–1070, U.S. Department of the Interior, U.S. Geological Survey (2015).

- W. L. Ellsworth, "Injection-induced earthquakes," *Science* 341(6142): 1225942 (2013) DOI: 10.1126/science.1225942.
- National Research Council, *Induced Seismicity Potential in Energy Technologies*, Chapter 2: Types and Causes of Induced Seismicity, Chapter 3: Energy Technologies: How they Work and their Induced Seismicity Potential (2013).
- A.A. Holland, "Earthquakes triggered by hydraulic fracturing in south-central Oklahoma," *Bulletin of the Seismological Society of America*, 103(3): 1784–1792 (2013).
- A. Holland, *Examination of possibly induced seismicity from hydraulic fracturing in the Eola Field, Garvin County, Oklahoma*, Oklahoma Geological Survey Open-File Report OF1-2011 (2011).
- K.M. Keranen, H.M. Savage, G.A. Abers, and E.S. Cochran, "Potentially induced earthquakes In Oklahoma, USA: Links between wastewater injection and the 2011 Mw 5.7 earthquake sequence," *Geology* 41(6): 699–702 (2013).
- K.M. Keranen, M. Weingarten, G.A. Abers, B.A. Bekins, and S. Ge, "Sharp increase in central Oklahoma seismicity since 2008 induced by massive wastewater injection," *Science*, 345(6195): 448–451 (2014).
- M.I. Hallo, I.L. Oprsäl, L. Eisner, and M. Ali, "Prediction of magnitude of the largest potentially induced seismic event," *Journal of Seismology* 18: 421–431 (2013).
- A. McGarr, "Maximum magnitude earthquakes induced by fluid injection," *Journal of Geophysical Research* (2014), DOI: 10.1002/2013JB010597.
<http://youtube/Uuh9IHavdvc>.
<http://youtube/ij9uR8vzmKg>.

Follow-up Assignment Questions

These are for the groups; follow-up question should address a completely different problem where correlation vs. causation is salient.

1. How can injection of fluid into the subsurface cause an earthquake?
2. Has the scientific community determined that there is a hazard of inducing seismicity by deep well injection?
3. If the possibility of a hazard has been established, what needs to be determined to assess any risk that might be associated with the hazard? What factors should be observed and measured?
4. If the risk can be assessed, what should policy makers or law makers do with this information?

Answers to Questions

1. Injection of fluids into the subsurface can cause earthquakes by changing the pore pressure in the rocks. This change can cause changes in the local stresses that support the rock and cause reductions in the friction across faults and fractures. Loss of friction causes the rocks to move in the ambient regional stress field. Hydraulic

stimulations cause very low magnitude (not felt) earthquakes by design as it expands existing fractures.

2. Yes, the United States Geological Survey has recognized that seismicity created by human activities is indeed a hazard, but must be assessed and understood differently from the natural tectonic earthquakes (see Petersen et al., 2015). The process of defining and quantifying the hazard is ongoing in the scientific community and is very dynamic.
3. The assignment of risk to the hazard of induced seismicity is in its infancy and under development in several venues. Based on the recommendations of a National Academy of Sciences study and several working groups of scientists and state regulators, several states have adopted a “stoplight” system of linking risk to operational activities. The risks of inducing levels of seismicity that could be damaging both in their magnitude and frequency are being linked to injection well and known fault locations, depths, volumes, and pressures. These geographic features are being considered in conjunction with proximity to human activities and developments. Additionally, several states, as well as oil- and gas-producing companies, are deploying seismographs to gather the needed information on earthquake occurrence, that is, magnitude, depth, and surface location.
4. The information that is being used to define the hazard is being incorporated into a risk assessment by state regulators. There may be risk assessment also taking place in the private sector. The policy makers and decision makers are using the information to construct siting and operational criteria that constrain the potential of the practice to induce damaging earthquakes. The prescription of restricting injection in areas and depth intervals (formations) that are deemed to be sensitive to failure is a part of the siting restrictions. Based on volumes and rates of injection, observed amounts of seismicity are monitored and assessed. If seismic events exceed established thresholds of frequency or magnitude, a series of restrictions come into force, beginning with enhanced monitoring and culminating with cessation and prohibition of the practice at a given locality.

Students' Guide for Case Study 3: Risk Assessment

OVERALL CASE STUDY GOALS

This teaching module contains three cases, along with instructional exercises and materials, to illustrate how scientific principles and processes are used to frame three basic concepts. The three concepts that are based on the scientific approach are:

1. Correlation is not the same as causation.
2. Hazard is not the same as risk.
3. Risk assessment includes establishing the degree of risk based on the evaluation of probability of occurrence and severity of negative consequences.

The topic used in this module to illustrate the application of scientific principles for analysis is the development of natural gas from shale deposits, or so-termed unconventional gas development.

In each of the three cases, a description of the circumstances surrounding the issue is framed, a selection of multimedia resources has been selected to demonstrate how using the concept can illuminate an understanding of the issue, and a structured exercise using the concept is provided to help students appreciate a real-world decision-making environment.

GENERAL APPROACH AND OUTCOMES

The overall strategy is to use case study analysis as a means to help you actively learn how using such techniques can be useful for addressing real-world problems. Problem-based learning using case studies encourages you to develop critical thinking and problem-solving skills within the context of a real-world situation or set of circumstances. The case study analysis process facilitates interaction with both the resource materials and other students as you collaboratively compile and analyze information, and derive conclusions, based on using fundamental principles. Part of the value of the process is learning how to interact with others in this overall process, a situation that will be repeated in the real world when nonscience decision makers will be interacting with technical experts and their scientific information.

Using the provided resources as documentation of the circumstances in the case, you will be instructed to analyze the situation; explore the situation from the viewpoints of different stakeholders or actors in the case; determine what issues need to be considered in order to develop various possible courses of action; make an analysis; and based on the results, provide recommendations for actions.

You will be assessed on how well you learn this process by two means:

1. The oral presentation of the recommendations of your group at the end of the class.

2. Your responses to a set of questions that you will answer after class and turn in on a later date.

Specific to this module, you are expected to learn that there is an important process to creating a risk assessment or analysis. It contains an assessment of the hazard and couples that with factors that could be responsible for elevating the hazard into a risk. Additionally, establishing the degrees of risk is a fundamental component of a risk analysis.

CASE 3: RISK ASSESSMENT

Activities

1. Before class:
 - a. Review all of the resources available for the case study; you will use these in groups in class and to answer the final question set (open book).
 - b. Read carefully the abstract and conclusions in:
 - i. <https://fracfocus.org/chemical-use/what-chemicals-are-used>
 - ii. <http://energyindepth.org/national/doe-report-finds-no-evidence-of-hydraulic-fracturing-contaminating-water/>
 - iii. Reference on hazard and riskNote the information in the diagrams, charts, and illustrations. Read the entire papers. Consider which stakeholders might find this information advantageous/disadvantageous.
2. In class (15 minutes). Together we will review and discuss “Danger of Fracking” website, US News and World report story, and recommendation letter in New York State Department of Health report. Consider, who are the stakeholders in the world of shale gas development? What are their interests?
3. In class, introduction (15 minutes). Form into groups to:
 - a. Define what the problem is from the various stakeholder perspectives.
 - b. Describe the stakeholder groups.
 - c. Describe their perceptions of and positions on the problem.
 - d. Describe the types of information/evidence parties are using as the basis for their positions.
4. In class, guidance (5 minutes). Listen as instructor speaks generally about the scientific concept of assigning causality using scientific principles and makes some recommendations on how it could be applied in this case.
5. Group work (20 minutes). Break into stakeholder groups and discuss your concerns about methane in groundwater. Based on the scientific concept and associated principles, recommend an approach to address the problem. This is to be done with data from the resources to address the questions as well as possible.
 - a. Must include some basic ideas about what data would be required, how it should be collected and analyzed, and what conclusions could be drawn.
 - b. May include aspects of uncertainty.

6. In class, reconvene (20 minutes). Groups report, receive feedback from each other on their recommendations.
7. In class, summary. Thoughts and guidance from instructor.
8. Follow-up assignment. Answer a set of questions using succinctly constructed responses based on what you have learned from the resources and class discussions.

Follow-up Assignment Questions

1. How can injection of fluid into the subsurface cause an earthquake?
2. Has the scientific community determined that there is a hazard of inducing seismicity by deep well injection?
3. If the possibility of a hazard has been established, what needs to be determined to assess any risk that might be associated with the hazard? What factors should be observed and measured?
4. If the risk can be assessed, what should policy makers or law makers do with this information?

Grading

1. Oral presentation of the group will be graded based on:
 - a. Comprehensiveness of content.
 - b. Clarity of message.
 - c. Effectiveness of use of time and visuals.
2. Follow-up questions will be graded based on:
 - a. Correctness of response.
 - b. Clarity and efficiency of expression.

Resources

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- W. L. Ellsworth, “Injection-induced earthquakes,” *Science* 341(6142): 1225942 (2013), DOI: 10.1126/science.1225942.
- National Research Council, *Induced Seismicity Potential in Energy Technologies*, Chapter 2: Types and Causes of Induced Seismicity, Chapter 3: Energy Technologies: How they Work and their Induced Seismicity Potential (2013).
- A.A. Holland, “Earthquakes triggered by hydraulic fracturing in south-central Oklahoma,” *Bulletin of the Seismological Society of America* 103(3): 1784–1792 (2013).
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- K.M. Keranen, M. Weingarten, G.A. Abers, B.A. Bekins, and S. Ge, "Sharp increase in central Oklahoma seismicity since 2008 induced by massive wastewater injection," *Science* 345(6195): 448–451 (2014).
- M.I. Hallo, I.L. Oprsal, L. Eisner, and M. Ali, "Prediction of magnitude of the largest potentially induced seismic event," *Journal of Seismology* 18: 421–431 (2013).
- A. McGarr, "Maximum magnitude earthquakes induced *by fluid injection*," *Journal of Geophysical Research* (2014), DOI: 10.1002/2013JB010597.
<http://youtube/Uuh9IHavdvc>.
<http://youtube/ij9uR8vzmKg>.