BASICS Business and Science: Integrated Curriculum for Sustainability

The Wicked Problem of Water Quality in the Mississippi River Watershed

Introduction

Water connects all elements of Earth's ecosystems, and human activities – biological, economic, and even recreational – change the chemical and biological nature of water. As such, maintaining the *quality* of water for humans and other organisms is a *wicked problem*, that is, a complex societal challenge that is impossible to fully solve. As we experience a growing world population, increasing consumption of resources, and global climate change, the problem of downstream water pollution becomes ever more complex. Many human activities impact water quality, including agriculture and food production in rural areas, sewage and wastewater disposal in urban areas, the generation of electricity, manufacturing and other industrial processes, and even the use of lifesaving pharmaceuticals that ultimately end up in our water.

Water supports life and is essential for our economy, but everything we do is likely to impact the quality of our water supply in some way. How do we provide for the water-related needs of a growing population, while ensuring an adequate supply of clean water for our neighbors and for future generations?

Clean Water and Sanitation is one of the 17 U.N. Sustainable Development Goals, the interrelated goals that help international policymakers identify targets and actions for ending poverty, reducing inequality, and protecting the planet. Sustaining resources and improving quality of life for more people on our planet requires planning that crisscrosses issues, time, and space. It's not difficult to imagine how clean water (Goal #6) is directly related to many of the other goals. Water is health, comfort, and security, and nobody on the planet can live without an adequate supply of clean water.

To begin to understand what makes water quality a "wicked problem," consider the **Mississippi River Watershed.** This vital region in the central U.S. is really a system of people living in cities, growing food, integrated with the natural environment, an essential player in regional and global trade, and a set of complex societal and environmental challenges that need to be solved. In this exercise, you will explore the way complex problems intertwine natural systems with human activities that provide for our physical health and economic well-being.

By the end of the exercise, you will be able to:

1. **Locate** and **describe** interactions between human and natural systems.
2. **Diagram** key components of a complex system focused on water quality and **identify** different stakeholder perspectives or interests associated with water use.
3. **Explain** how differing power dynamics among stakeholder creates conflict and the potential for social/environmental injustice.

What do we mean by a "system", and how can it help us analyze complex problems?

A "system" is an interconnected group of parts that define a unified whole (Wikipedia). We can study ecosystems (interrelated organisms and the components of their natural environment), social systems (human communities and their physical infrastructure), economic systems (people and institutions involved in the production and distribution of goods and services) and many other types of natural and human-created systems. In order to analyze a system, you must be able to identify the critical (or key) components of the system and understand how they interact. You also need to have some idea of how a disruption in one part of the system causes a reaction in other parts of the system. We'll explore this in more detail by looking at water pollution in the Mississippi River Watershed, a complex integration of natural and human systems.

The Mississippi River Watershed as a Complex System

The Mississippi River system is vast. The headwaters of the Mississippi River begin in Minnesota and courses through 10 states, before it discharges into the Gulf of Mexico. The Mississippi River is the second longest river in the United States at 2,202 mi (3,544 km). The longest river is the Missouri River at 2,341 mi (3,768 km), but because it drains into the Mississippi, the Mississippi River *drainage basin* or *watershed*, is actually considered the largest. Covering an area over 1,245,000 mi^2 (3,220,000 km^2), the Mississippi River watershed encompasses over 40% of the contiguous U.S. and is one of the largest drainage basins in the world. Practically, that means any rainwater (or melting snow) that falls in a 32 state area is carried downstream to the Gulf of Mexico.

Clearly such a large region contains lots of people, industry, and farmland, not to mention the major cities of Minneapolis, St. Louis, Memphis, and New Orleans. The sheer size of the Mississippi River watershed means that human activities — like the intensive agriculture required for our food supply, livestock, and global trade —are intimately connected to the natural and human systems that move water downstream and keep the water clean for the plants and animals inhabiting it. Since all water (for example, rainwater, snowfall, surface streams, groundwater, and water vapor in the atmosphere) is connected, the "fingerprint" from human activities like farming, waste disposal,

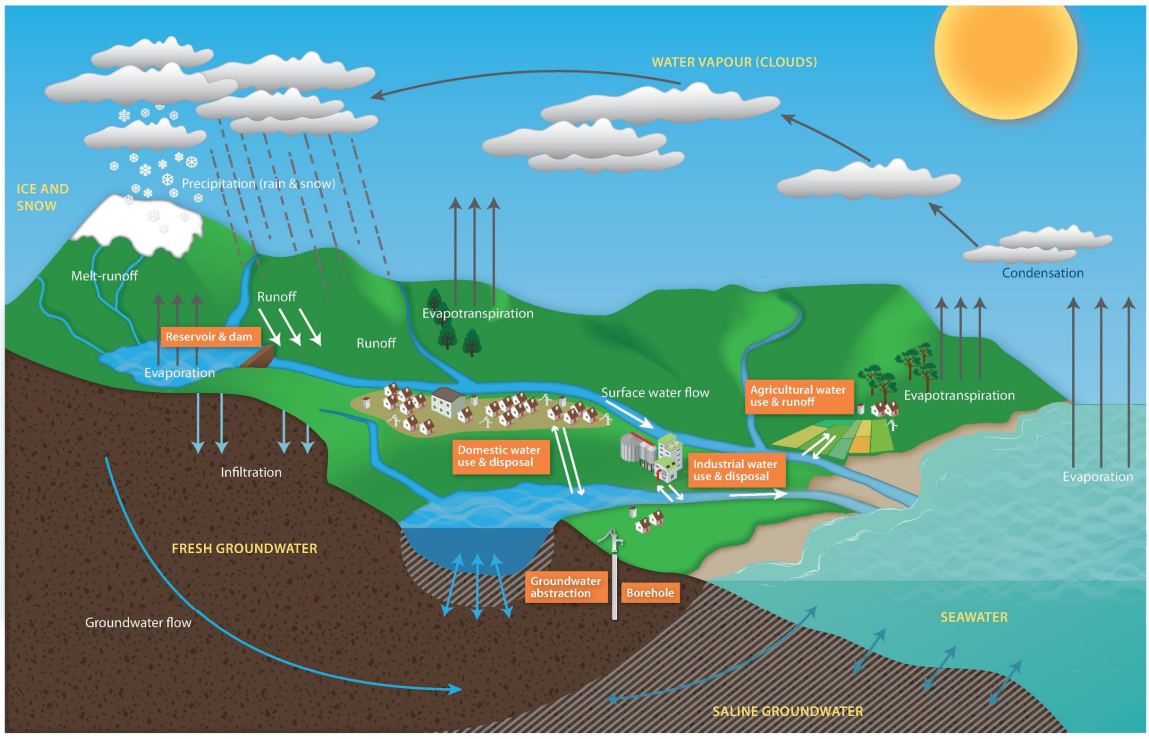
transportation, or even just urban street runoff, all moves downstream. When the chemical or biological fingerprint has a negative impact, that's downstream pollution.

The Water Cycle and Nitrogen in the Mississippi River Valley

To illustrate the "wicked" nature of maintaining water quality downstream, we're going to zero in on a significant pollutant in the Mississippi River system: *nitrogen*. Like water, nitrogen is everywhere. It comprises most of the air we breathe and is a component of all living matter, making it critical to life on Earth. Humans have dramatically increased the amount of nitrogen that is biologically available by harnessing it as fertilizer. As it moves and changes chemically, too much nitrogen in the wrong place and in the wrong form can be a pollutant. But because it's so abundant, so essential, and it is created and distributed by such a wide range of human activities, it provides a useful illustration of a wicked problem associated with a common chemical pollutant in river systems.

Before we identify how and where nitrogen problems arise from human activities, we need to understand where those activities interact with the *water cycle*. You've probably been learning about water and the water cycle since you were a child. The diagram below illustrates the movement and change of water and several ways that the natural movement of water intersects with human activities. It's clear that there are lots of opportunities for human systems and natural systems to interact around water.

The water cycle including some human activity



1. Watch this video for a quick refresher on the water cycle and this video on human aspects of the water cycle.
2. Watch this video that illustrates one kind of interaction: connecting fertilizer runoff with drinking water.
3. And finally, view this interactive story of nutrient pollution in the Mississippi River watershed.

Part 1: Drafting a Stakeholder Map for Nitrogen in Water Cycle

It should be apparent now why so many people in the Mississippi River Watershed are connected in some way with nitrogen. In the next part of this exercise, we're going to define how these interests are related, that is, how they overlap and how they may conflict based on the perspective of the *stakeholder*. A stakeholder is any individual or group that has an impact on or is affected by the system of interest. They are components in a system.

Goal: Recall or review the introductory materials, and map the stakeholders involved in the nitrogen pollution in the Mississippi River Watershed, and the relationships among those components/stakeholders.

Materials and constraints. Use pencil, pen, or permanent marker and a blank white 8.5 x 11 or larger paper to create your stakeholder map (or use an online mapping program, if directed by your instructor). Write in uppercase/capital letters only, as this tends to make handwriting easier for others to read. Sticky notes can also be used for some of the components.

Your instructor will provide detailed directions on how to construct your stakeholder map.

Part 2: A Town Meeting on Nitrogen in Mississippi River

In this role-playing game you will be assigned a stakeholder group to explore specific issues related to nitrogen in the Mississippi River watershed in the fictional town of Misiziibi (the Ojibwe Native American name for the Mississippi river, meaning "Great River"). This will take place in a mock town meeting where the Mayor (your instructor) is requesting input for how to address the challenges, and your input will reflect consideration of your stakeholder interests. Please review the rubric so that you are fully prepared.

Goal*:* Make a case for water decisions that reflect your stakeholder perspective. Note that you will also need to take notes on the interests of other stakeholders, so that you understand how interests of some stakeholders may result in vulnerability, or challenges of environmental injustice for other stakeholders or community members not present (i.e., when poor communities, communities of color, or other marginalized groups are disproportionately impacted). Each group should appoint an "advocate" that keeps the group cognizant of power dynamics among the stakeholder groups that can lead to various forms of social or environmental injustice.

Each group of stakeholders will select one spokesperson to make their statement. The other group members should help in answering questions. Groups represent their stakeholder's interests and perspectives throughout the exercise and hold their questions until all groups have presented.

Each group will have 5 minutes to present their position.

Roles

Group 1: You represent family farms in the upper Midwest with large acreages of corn and soybean fields. You are a sixth generation farmer and are proud of the work that you do. Like other farmers, you add nitrogen fertilizer into the soil to increase crop yield. However, despite increasing yield, you also face increasing costs of fertilizers, pesticides, irrigation, seeds, land and equipment, and increasing competition from international trade squeezing your already tight profit margins. Because the rate of nitrogen use by U.S. farmers is now 40 times higher than it was in the middle 1900s, and we know more about the environmental and health impacts of nitrogen pollution, you are facing increased regulation and pressure from environmental groups to reduce the use of nitrogen fertilizers. You know that if you do reduce your use, your crop yield will drop, and you might not be able to break even financially.

Use these resources to learn more:

- Cropland used for crops (in 1,000 acres): https://arcg.is/1TmXaj
- Value of crop production (in 1,000 USD): https://arcg.is/niHe1
- Nitrogen used on corn as fertilizer (pounds per fertilized acre receiving nitrogen): https://arcg.is/eiXjX
- Total nitrogen yield (kilograms per square kilometer per year): https://arcg.is/0GaeL8
    - The nitrogen yield of a given watershed is calculated by dividing the nitrogen load by the watershed area

Group 2: You represent the fisheries industry that relies on fish harvest from the Gulf of Mexico. While you live in Misiziibi, you work on fishing boats in the Gulf. In addition to the risky nature of the business, costs of maintaining a fishing business are high, between permits, boats, labor, and fuel. Competition with imports is a looming challenge, as countries with less rigorous fishery and aquaculture laws are able to out-produce American seafood businesses and drive prices down. On top of it all, you are noticing the size and duration of hypoxia, or dead zones, in estuarine and coastal bottom waters has increased at an alarming rate for the past 20

years. Hypoxia is largely the result of excess nitrogen carried by Mississippi River water flushing into the Gulf of Mexico. Hypoxia kills some fish and squeezes others into small areas, where they are easy picking for predators. As a result, you have smaller and smaller yields, while having to go into deeper and deeper waters. You want upstream businesses and municipalities to reduce their nitrogen footprint, so that you can stay in business.

Use these resources to learn more:

- Share of nitrogen flux (delivery) to Gulf of Mexico (in percent): https://arcg.is/1aiiOz0
- Commercial fisheries' domestic landings (in metric tons): https://arcg.is/1CTXGX
    - Commercial fishing is the activity of catching fish and other seafood for commercial profit, mostly from wild fisheries.
- Aquaculture sales totals (in USD): https://arcg.is/1DvjWD1
    - Aquaculture is a broad term used to refer to any *farmed* aquatic species, from freshwater trout to saltwater shellfish. Farm-raised catfish is the largest aquaculture industry in the U.S. Aquaculture production also includes bivalve mollusks such as oysters, clams, and mussels, as well as salmon and shrimp.
- Gulf of Mexico Dead Zone-The Last 150 Years. USGS FactSheet 2006-3005: https://pubs.usgs.gov/fs/2006/3005/fs-2006-3005.pdf

Group 3: You represent the municipalities for which you must supply drinking water to the residents and treat all of the sewage. The river water coming into the drinking water plant exceeds the maximum contaminant level (MCL) for both nitrate and nitrite as defined by the USEPA. For the sewage, you have a discharge permit that requires further reduction of nitrogen. You are getting reports from local health centers about increasing incidences of stomach or liver illnesses, respiratory problems, and skin problems that might be associated with excess nitrate in the water supply. You fear that your town may get on the "dirty waters list" under the federal Clean Water Act. To help ensure the safety of your community and other communities downstream, you need to upgrade drinking water treatment plants and reduce the nitrogen discharged through your sewage treatment plant. However, advanced treatment that involves denitrification, which can remove up to 78 percent of nitrogen, seems prohibitively expensive. Given your current budget situation, your town cannot afford the upgrade without raising revenue (i.e., special assessment tax). In fact, you actually need to lower the costs of wastewater and drinking water utilities due to a large number of complaints from residents about their utility bills.

Use these resources to learn more:

- Vedachalam, S., Mandelia, A.J., and Heath, E.A. 2018. Source Water Quality and the Cost of Nitrate Treatment in the Mississippi River Basin, Northeast-Midwest Institute Report, 44 pp., http://www.nemw.org/wp-content/uploads/2018/05/NEMWI_WaterQuality_NitrateCost_2018.pdf

Group 4: You represent the citizens of Misiziibi and you have seen your rates for water and sewage increase over the last 10 years, yet you hear a lot about nitrogen pollution in the Misiziibi water supply and are worried about the health effects. You and your family members work in the town or surrounding agricultural or fisheries industry. Employment in the area has not been consistent in recent years. Many of your friends and family are barely getting by and have poor health. You would welcome more well-paying jobs and stable health insurance coverage for your family and friends. You have had your wells tested, and the levels of nitrate and nitrite have been increasing, and at times exceeding the MCL. You want the town to do a better job with purifying the drinking water supply.

Use these resources to learn more:

- Percent of population with no health insurance coverage (at the county level): https://arcg.is/0jDumG

- Percent of population below poverty level (at the county level): https://arcg.is/KvDvu
- Median household income (in USD, at the county level): https://arcg.is/1nCOnm
- Percent of population that are nonwhite (at the state level): https://arcg.is/0rW0Lv
- Nitrate concentration in groundwater (percentage of state area with groundwater nitrate concentrations > 5 mg/L): https://arcg.is/9CO9W0
    - While nitrate does occur naturally in groundwater, concentrations greater than 3 mg/L generally indicate contamination, and concentrations over 1 mg/L nitrate indicate human activity. EPA's MCL for nitrate set to protect against blue-baby syndrome is 10 mg/L.

Group 5: You represent a small brewery that wants to expand its operations due to increasing beer consumption in the region. The company is planning on building a new plant that will bring much needed employment to the area. While the municipality and citizens of Misiziibi welcome new businesses in the region, you are facing resistance from local environmental groups that your new plant will only make the nitrogen pollution worse. They are running campaigns highlighting the fact that brewery wastewater has high nutrient content, including nitrogen. While water quality is a concern, you must be cognizant of costs in order to ensure a healthy profit margin for your owners.

Use these resources to learn more:

- https://wwf.panda.org/?172161/Water-footprint-of-beer-more-on-the-farm-than-in-the-brewery

Group 6: You represent a local non-governmental organization (NGO) that wants to protect a local endangered aquatic plants and habitat for riparian zone (riverside and floodplain) flora and fauna. You have seen eutrophication (excess nutrients) in the wetlands that is killing off the protected plants and animals. You want the town to impose restrictions on farmers' nitrogen fertilizer usage, reduce stormwater runoff from Misiziibi, upgrade the wastewater and drinking water treatment facilities, restore or enhance riparian buffers, and take a tougher stance on commercial businesses that contribute to the problem.

Use these resources to learn more:

- NPR. 2020. Absentee Landlords Interfere with Farmers Protecting Water, Soil: https://www.npr.org/2020/07/14/890716855/absentee-landlords-interfere-with-farmers-protecting-water-soil
- Nutrients in the Nation's Streams and Groundwater, 1992–2004: https://pubs.usgs.gov/circ/1350/
- Riparian buffer zones affect the quality of midwestern streams and rivers: https://mn.water.usgs.gov/nawqa/umis/pdf/nest_RiparianPage.pdf

Other Resources

- Alley, W. and R. Alley. 2020. The War on the EPA: America's Endangered Environmental Protection. Chapter 4: A Wicked Problem
- USGS. 2000. Nitrogen in the Mississippi Basin-Estimating Sources and Predicting Flux to the Gulf of Mexico. Fact Sheet 1350-00

Part 3: Creating a Revised Stakeholder Map for Nitrogen in the Mississippi River Watershed (whole class)

Goal: Create a *single* map with your entire class that reflects your collective and revised understanding of the wicked problem based on the role-playing activity in Part 2.

Instructions

1. ***Preparation.*** The instructor will open a shared board on Mural (or other online mapping program).
2. ***(Individually).*** Convert each of the items from your original map to separate post-its in the shared Mural board. If appropriate, add or remove items and relationships based on the role-playing exercise/debate.
3. ***(As a Team or As a Class).*** Work together to create a unified map as a class. Move items around, group together or combine similar items as needed, and add new relationships based on your revised understanding of the wicked problem following the role-playing exercise/debate.
4. ***(Optional)*** Use the Noun Project to enhance your map with icons.