Modeling Ecosystem Impacts of Flooding: A Real-World Ecology and Engineering Challenge

(180 mins)

Authors

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SUBJECT/GRADE LEVEL

Subject Area: Biology & Environmental Science

Grade Level: High School

Materials

- Rubber ducklings - 2 per group of 4 students
- Plastic tub or tray filled with water
- Straws
- Small pebbles, sand, and larger rocks
- Orbeez (to represent aquatic life)
- Modeling clay or sponges (to create dams)
- Test Strips Accurate Water Quality Testing Strips for Ammonia pH Total Alkalinity Carbonate Hardness Free Chlorine Nitrate Nitrite Temperature - Amazon Link ($10 for 150 strips)

STANDARDS

Next Generation Science Standards

- **HS-LS2-6**: Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
- **HS-ESS3-1**: Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate affect human activity.
- **HS-PS2-1**: Analyze data to support the claim that Newton's Second Law of Motion describes the mathematical relationship among the net force, mass, and acceleration.

Mathematics Standards | Common Core State Standards

- **CCSS.MATH.CONTENT.HSG.SRT.A.3** – Use properties of similarity transformations to model topographic changes in flooded areas.

English Language Arts Standards | Common Core State

- **CCSS.ELA-LITERACY.SL.11-12.1.A** – Participate in collaborative research-based discussions on ecological engineering and community resilience to flooding.

LESSON OBJECTIVE(S)

Students will be able to:

- Use models and simulations to explore ecological impacts of flooding on riverine and coastal ecosystems.
- Analyze hydrological data to determine effects of human interventions (e.g., levees, flood walls) on natural systems.
- Identify career pathways in hydrology, ecology, civil engineering, and scientific research.

CAREER CONNECTION(S)

Mentor Background:



Dr. Gaurav Savant, Ph.D., is a senior research hydraulics engineer at the U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL) in Vicksburg, Mississippi. With a Ph.D. in Civil Engineering from Mississippi State University and a bachelor's degree from Punjab Engineering College, Dr. Savant leads advanced research in numerical and computational fluid dynamics (CFD). He spearheads the USACE Coastal Compound Flood research and specializes in hydrodynamic simulations of estuarine, coastal, and riverine systems under the pressures of climate change.

His current projects include modeling for ecological restoration of the Los Angeles River, flood control in Arecibo, Puerto Rico, CFD support for military expeditionary fueling systems, and sediment simulations for the Mississippi River and OMAR study. An accomplished researcher, Dr. Savant has authored over 45 peer-reviewed publications and serves on editorial boards for top journals in water engineering. He also holds adjunct faculty positions at several universities and remains a dedicated contributor to both civil and military engineering missions of the USACE.



Dr. David Smith, Ph.D., is a distinguished Research Ecologist at the U.S. Army Corps of Engineers' Engineer Research and Development Center (ERDC), Environmental Laboratory. His research primarily focuses on ecosystem modeling, habitat restoration, and the ecological impacts of infrastructure and land use. Dr. Smith is widely recognized for developing science-based tools to support environmental decision-making in water resource management, wetland conservation, and ecological resilience. His work integrates field data with advanced modeling techniques to better understand complex ecological processes and guide sustainable development practices. Through collaborative research initiatives, Dr. Smith contributes to national efforts in restoring ecosystems and enhancing biodiversity in both military and civilian contexts.

STEM Careers: Environmental Scientist, Hydrologist, Ecological Modeler, Civil Engineer (Water Resources), GIS (Geographic Information System) Specialist

ENGAGEMENT - 15 minutes

Brief Description: Students will watch a video of the recent Texas flash floods to observe the speed and impact of rising waters. They'll then simulate a floodplain using real topographic data to explore how floods spread and affect both infrastructure and ecosystems. The class will discuss safety strategies, ecological impacts, and how scientists like Dr. Smith and Dr. Savant use models to predict and manage flood risks. Finally, students will analyze local flood risk maps in teams and share their insights on a class synthesis board.

Procedures:

1. Students will watch the video of the recent flood that happened in Texas- showing the devastating speed and scale of the Texas flash floods, how water surged rapidly, overwhelming infrastructure and natural barriers https://youtu.be/QXzbCiqvcBk

They'll examine how floodwaters spread, how human interventions impact ecosystems, and how scientists like Dr. Smith and Dr. Savant contribute to designing sustainable solutions.

Questions to be asked after the video:

- How does seeing the floodwaters rise so quickly change your understanding of flood risks?
- What are some immediate safety strategies that schools or communities can implement when faced with sudden flooding?
- Impact on Infrastructure & Ecosystems
- From the video, what types of infrastructure (e.g., roads, bridges) were most impacted? How would these disruptions affect emergency response or daily school operations?
- Which ecological components—trees, soil, habitats—appeared most vulnerable? How might we prepare ecosystems to better handle such events?

Synthesis board:

1. Students will individually analyze a flood risk map of their local region, share their opinions by filling the sticky notes and posting on the synthesis board.
2. Class discussion: What ecosystems are at risk? How do engineers and ecologists work together to solve these challenges?
    - Synthesis Board: Click here for link
    - Synthesis Board on White board Example: Click here for link

EXPLORATION - 30 minutes

Brief Description: In this hands-on activity, students will explore how natural and man-made features influence water flow and flooding. Using rubber ducks, water trays, and materials like sand, rocks, and clay, they'll simulate dams, terrain, and aquatic ecosystems. Students will observe how water movement changes with different conditions, how obstacles affect flow, and how flooding impacts aquatic life. Through guided questions, they'll connect these models to real-world flood dynamics and ecosystem effects.

- Modeling Flood Dynamics with Rubber Ducks Teacher Key: Click here for link
- Teacher Rubric: Modeling Flood Dynamics with Rubber Ducks: Click here for link

Materials (per group):

- 1 plastic tub or tray filled with water
- 2–3 rubber ducklings
- Straws
- Small pebbles, sand, and larger rocks
- Orbeez (or similar water beads)
- Modeling clay or sponges (for dams)

Procedure:

Part 1: Water Movement & Debris

1. Gently place 1–2 rubber ducklings on the surface of the water.
2. Use a straw to blow gently across the surface, creating ripples.
3. Observe how the ducks move with the water.
4. Record observations: How does the water's movement affect the direction and speed of the ducks?

Part 2: Building and Breaking a Dam

1. Use modeling clay or a sponge to build a small dam at one end of the tub.
2. Slowly pour water behind the dam to simulate buildup.
3. Once the dam "breaks," observe how the water flows and how the ducks respond.
4. Record observations: What happens upstream and downstream when the dam fails?

Part 3: Simulating Terrain

1. Scatter small pebbles, sand, and larger rocks into the tray to create varied terrain.
2. Blow through the straw again or pour water gently to simulate flow.
3. Observe how the terrain alters the path of the ducks and water movement.
4. Record observations: How does terrain shape water flow and flooding?

Part 4: Impact on Aquatic Life

1. Add several Orbeez into the water to represent aquatic organisms.
2. Stir up sand or dirt to simulate sediment during a flood.
3. Observe how sediment affects visibility and the movement of the Orbeez.
4. Record observations: What impact might this have on real aquatic life?

Wrap-Up: Group Discussion

- What did you notice about how the water moved in different setups?
- How did the obstacles affect where the duck traveled?
- What does this activity help us understand about how floods affect real ecosystems?
- How does sedimentation impact water clarity and aquatic organisms?

EXPLANATION - 20 minutes

Brief Description: This lesson introduces students to the concept of ecosystem stability, focusing on the ability of ecosystems to maintain structure and function over time and in response to disturbances. It explains the two main components of stability, resistance and resilience and highlights the role of biodiversity in promoting both. Students explore how natural (e.g., storms, fires) and human-caused changes (e.g., pollution, habitat fragmentation, invasive species) affect ecosystem stability. The lesson includes real-world examples, key vocabulary (e.g., keystone species, habitat islands), and discussion questions to deepen understanding.

- **Powerpoint:** Click here for link

Procedures:

1. Begin with a Warm-Up
    - Ask students: "What makes an ecosystem stable?"
    - Have students write a quick response or discuss with a partner.
2. Introduce Key Vocabulary
    - Briefly define: ecosystem stability, resistance, resilience, biodiversity.
3. Present the PowerPoint in Segments
    - Slides 1–3: Define ecosystem stability, structure vs. function.
    - Slides 4–5: Discuss resistance and resilience.
    - Slides 6–7: Explore biodiversity's role in stability.
    - Slides 8–12: Examine natural and human-caused changes to ecosystems.
4. Engage Students with Guided Questions (throughout)
    - Ask included questions from the slides (e.g., "What happens when biodiversity is lost?")
    - Encourage students to take notes or respond in journals.

5. Class Discussion or Think-Pair-Share
    - Discuss how human actions affect ecosystem resilience and resistance.
    - Use examples like invasive species or habitat loss.
6. Wrap-Up with a Summary or Exit Ticket
    - Students answer: “How do biodiversity and resilience affect stability?”

ELABORATE - 45 to 60 minutes

Brief Description: In this activity, students will step into the shoes of different stakeholders involved in a dam project. Through research, role-playing, and debate, they will explore the ecological and socio-economic impacts of dams and gain a nuanced understanding of how human actions affect our environment.

- Teacher Instructions: Click here for link
- Student Graphic Organizer: Click for link
- Audience Participation Graphic Organizer: Click here for link
- Student Debate Rules Handout: Click here for link
- Stakeholder Roles for Dam Debate (Teacher Key): Click here for link
- List of stakeholder roles for random draw (optional): Click here for link
- Debate Rubric: Click here for link

Procedures:

1. Introduce the Dilemma: Engage students with a video or images of rivers and dams, then introduce the "Local Dam Project" scenario.
2. Assign Stakeholder Roles: Divide the class into 4-6 groups and assign each a specific stakeholder role (e.g., Hydropower Company, Environmental Conservationists).
3. Initial Brainstorm & Brief: Groups brainstorm initial concerns/benefits from their stakeholder's perspective and create a short "Stakeholder Brief" poster.
4. Explain Debate Structure: Outline the debate rules, timing for each segment, and review the assessment rubric.
5. Research & Argument Development: Groups research their assigned role, gathering scientific, economic, and social evidence to support their arguments.
6. Construct Opening Statements: Each group prepares a compelling opening statement (3-4 minutes) outlining their position.
7. Prepare Rebuttals & Questions: Groups anticipate opposing arguments and prepare counter-arguments and questions for other stakeholders.
8. Conduct Opening Statements: Each stakeholder group presents their prepared opening statement.
9. Facilitate Debate Rounds: Lead a dynamic discussion with focused rebuttals, an open forum for cross-examination, and a round for presenting mitigation/alternative ideas.
10. Conclude & Reflect: Wrap up with closing statements from each group, followed by a whole-class debrief and individual written reflection.

EVALUATION - 45 to 60 minutes

Brief Description: This culminating lab serves as the final assessment for a biology unit on ecosystems and environmental sustainability. Students will apply their understanding of abiotic and biotic factors by conducting water quality tests on 4–5 different freshwater sources, measuring nitrates, nitrites, ammonia, carbonate (alkalinity), and water hardness. Through data collection, analysis, and a Claim-Evidence-Reasoning (CER) response, students demonstrate their ability to evaluate ecosystem health and human impact using real-world scientific methods.

- Testing The Water Lab Procedure: Click here for link
- Testing The Water Lab Data Table: Click for link
- Testing The Water Lab Questions: Click here for link
- Testing The Water Lab Rubric: Click here for link

Procedures:

Thoroughly describe the procedures for the activity, including time frame. Be sure to include background information of the content, teacher and student actions, opportunities for formative assessment, hyperlinks, and possible adaptations for individual learners and/or virtual options.

1. Prep 3–4 Distinct Water Samples - Label clearly: Sample A (e.g., Pond), Sample B (River), Sample C (Tap), Sample D (Aquarium). Add safe trace amounts of fertilizer or aquarium solution to simulate nitrate/ammonia differences if real sources aren't varied enough.
2. Set Up Lab Stations with Testing Kits or Strips. Include materials for testing: nitrates, nitrites, ammonia, carbonate, and hardness. Provide extra test strips in case of errors and label waste cups for disposal.
3. Review Safety Guidelines. Goggles and gloves required. No direct skin contact or ingestion.
4. Distribute Student Handouts which include: data tables, analysis questions, and a CER writing prompt. Use laminated handouts or clipboards if working outdoors or near sinks.
5. Form Lab Groups (2–4 Students). Assign or allow choice depending on class dynamics.
6. Demonstrate One Water Test for the Class. Walk through one full test (e.g., nitrate strip) and how to record data.
7. Monitor Group Testing & Assist with Results. Ensure proper technique and timing for color comparison. Have students take a photo of each test strip next to the color key if timing is difficult.
8. Guide Students in Data Recording & Table Completion. Make sure students record both color results and ppm estimates. Encourage students to annotate results with "safe/unsafe" or "high/low" as they go.
9. Facilitate Analysis & CER Writing. CER prompt: Make a claim about which water sample best supports a sustainable ecosystem, using at least three data points as evidence.
10. Collect Handouts or Have Students Present Findings. Use the rubric to assess lab performance, data accuracy, analysis, and reasoning. Optional - Allow optional short group presentations to reinforce oral scientific communication.

REFERENCES

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The author(s) acknowledge the utilization of ChatGPT, a language model developed by OpenAI, in the preparation of this lesson plan. ChatGPT was employed in the following manner(s) within this plan [grammatical correction, lab procedure creation, answer key creation, student handout and rubric creation.