NATIONAL SESYNC SOCIO-ENVIRONMENTAL SYNTHESIS CENTER

Teton Dam Failure, Idaho, June 5, 1976. Open source image from waterarchives.org and Wikimedia Commons.

Lesson: Ecological Resilience: The American Dam, Past and Future

By Heidi Scott, SESYNC | June 29, 2022

Overview:

The UNESCO International Hydrological Programme's recent report on Climate Risk Informed Decision Analysis (CRIDA) gives an overview of the socio-environmental challenges to planning for resilient and ecosystem-supporting water infrastructure in our era of intensified climate change. They explain: "Water resources management takes all [the physical complexities of hydro-engineering], and adds the exasperating human element—institutions and infrastructure, policies and politics, demographics and demagogues, cooperation and conflict. The hard science and engineering run up against the soft science and culture. And as the water management truism states, 'the soft parts are hard.' The hard parts are not so easy either" (page 10). This lesson provides perspective on how to bridge the engineering, ecological, and social elements of hydrology with the risk-based factors imposed by climate change. It starts with a retroactive view of dam-building history and the residual effects across the vast network of American rivers. It continues with an in-depth case study and debate on the best socio-environmental practices that result in resilient and equitable outcomes.

Assumed Prior Knowledge:

For learners of all levels to integrate social and cultural factors with ecological and economic imperatives for resilient water infrastructure that can endure the exigencies of 21st-century climate change.

Learning Objectives:

- Learn and use critical hydrology terms and concepts to develop plans for resilient and equitable solutions in dam building and removal.
- Use the history of dam construction to understand how a minority of stakeholders has wielded disproportionate influence in past decision making.
- Develop debate-based rhetoric, logic, and concessions in a dam-removal case study.
- Synthesize history, geography, hydrology, and stakeholder dynamics to create an equitable solution that emphasizes resilient infrastructure and/or natural and variable flow states.

Key Terms and Concepts:

resilience; hydrology; dam building; fish habitat restoration; decision scaling; green infrastructure; hydropower; hydrologic connectivity; engineering design; ecosystem services; functional flows; climate change; environmental justice

The Hook (suggestions for quickly engaging students):

Downstream view taken on the bank of the Colorado River in Glen Canyon of Hidden Passage Canyon before the construction of Glen Canyon Dam, c. 1958. Open source image via Wikimedia Commons.

- Show students this image and read out loud the remarks from the writer Edward Abbey in 1981:

> *"In 1962, they closed the bypass tunnels of Glen Canyon Dam and began the inundation of Glen Canyon—the place that only a few ever knew. Perhaps a few hundred, a few thousand, were privileged to make that enchanted journey down the Colorado from Hite to Lee's Ferry, through this canyon that Major Powell named Glen. What those few saw was first of all the living flowing river, with its riffles and minor rapids—nothing serious or difficult. It was in fact*

a trip that any could make, on their own, with almost any kind of equipment—no need there for professional guides or commercial outfitters—from Cub Scouts to little ole ladies in inner tubes, with or without life jackets, anybody could do it. In and along the river were sandbars, beaches, willow groves and glades of cottonwood, and the innumerable grottoes, caves, arches, amphitheaters, coves, [and] side canyons along the way so aptly named by Powell and his men: Cathedral in the Desert, Music Temple, Hidden Passage, Dungeon Canyon, Forbidden Canyon, to name but a few. Up these side canyons were great natural bridges, like Gregory, now submerged, and countless pools, streams, waterfalls, springs, and seeps. Everything was full of life—not only deer and lion but also fox, beaver, coyote, bighorn, bullfrogs and gopher snakes, great horned owls and great blue herons, wood ibis, killdeer, sandpipers and redtail hawks. Plus the ancient human history of the canyon: the hundreds of ruins, granaries, shelters, and villages left by the Anasazi, the priceless rock art of pictograph and petroglyph. All this you could've known in Glen Canyon, plus a scenic grandeur equal to though quite different from Grand Canyon, or Desolation, or Hells Canyon, or Big Bend. All this plus the sweetness and adventure and wonder of unspoiled wilderness. All this and much, much more.

And they took it away from us. The politicians of Arizona, Utah, New Mexico, and Colorado, in cahoots with the land developers, city developers, industrial developers of the Southwest, stole this treasure from us in order to pursue and promote their crackpot ideology of Growth, Profit, and Power—growth for the sake of power, power for the sake of growth. We can see now that Glen Canyon Dam was merely a step toward the urbanizing, industrializing, and—probably—militarizing of the American West. But Glen Canyon Dam remains particularly painful and obnoxious—not only a symbol but ongoing exemplification of what greed and stupidity can do to the American land. Surely no man-made structure in modern American history has been hated so much, by so many, for so long, with such good reason, as Glen Canyon Dam."

American Dam, Past and Future Slides.pptx

- This speech illuminates the perspective of a stakeholder—a naturalist, who decries the economic development motivations that resulted in Glen Canyon Dam's construction.
- Have students spend 5 minutes listing what other stakeholders were involved or excluded in the decision process (e.g., politicians, Native Americans, the hydropower industry). Who and what have benefitted from this massive infrastructure project that is an emblem of 20th-century economic-led development? Who and what has suffered? What are the notable legacies of this project?
- What is Glen Canyon Dam's status today as climate changes and the West dries out? As of this writing (June 2022), the hydroelectric power that is distributed to Wyoming, Utah, Colorado, New Mexico, Arizona, Nevada, and Nebraska is at only 60% capacity, and if the water in Lake Powell drops another 45 feet (to 3,490 ft), hydroelectric generation will have to shut down.
- If the project engineers c. 1960 had been able to glimpse the future, how might knowledge of climate change and concern for all stakeholders have changed the Glen Canyon Dam project?

Teaching Assignments

1. **Dam Dismantling and Resilience Building** (One, 75-minute class)

   Though massive dam projects continue apace in the developing world, in the United States there is significant movement toward dam removal to recover lost ecosystem services, especially fish-spawning habitat.

   - Have students scan through this list of 25 dam removal projects slated for 2022. Have each student choose one project to explore in greater depth using online research. To get comprehensive coverage of the list, you might assign sites to students.

- In a 20-minute breakout session, individual students should list 1) stakeholders and their positions, 2) anticipated ecosystem changes (+/-) that will result, especially related to resilience, 3) anticipated economic effects of dam removal, and 4) any further questions to pose to the contact person listed for each site.
- Organize students in four groups according to the geography of their site: East Coast, Midwest, Mountain West, and West Coast. For 10 minutes, have them compare the ecological, economic, human, and cultural significance of their sites to seek commonalities. For example, students will find that the East Coast projects are often old, small dams that powered now-defunct industries and serve no further role; in the West, however, low water supply, fish spawning, and Native American rights can be the leading motivators for dam removal. What other cultural, geographical, and ecological effects help them cluster regional themes of how dams are decommissioned and removed?
- Next, as a whole class, ask the regional groups to share their common findings and seek both similarities and contrasts that have motivated dam removal across geographies. In terms of resilience to both floods and droughts, how will dam removal affect ecosystem services? (As background, you may want learners to quickly read the SESYNC "Resilience" Explainer.
- Conclude this session by returning to the massive Glen Canyon Dam. Encourage creative speculation on the 5-year, 50-year, and 500-year future of this exemplar of economic-led American infrastructure. Seen from a 2022 perspective, is Glen Canyon Dam an emblem of the success of Big Engineering, or does it capture the myopia, conquest mindset, and revenue drive of a subset of stakeholders from the mid-20th century? Since the issue is complex, don't force the students into a singular view of the historic and ongoing impact of Glen Canyon Dam.

2. **Sustainable Water Management and Resilience Debate: Matilija Dam** (Two, 75-minute classes)

   This second lesson should be completed after the first. It requires deeper reading on the science of resilience in water systems and provides a case study of a dam removal project in California.

   - As preparation before class (rather than as in-class activity), have students carefully read excerpts taken from the articles by Grantham and Poff). (The excerpts that students should read are highlighted are in the PDF versions below.)

     Reading 1 – Grantham et al. 2019 (highlighted).pdf

     Reading 2 – Poff et al. 2015 (highlighted).pdf

     Have them list and define a few basic terms: **resilience**, **functional flow** versus **static optimization**, **hydrologic connectivity** in four dimensions, and how the **homogenization of flow routines** negatively affects ecological resilience.
   - Next, review the stakeholders involved in water infrastructure decisions: water managers, politicians, property owners, farmers, naturalists, and cultural groups including Native Americans. Push your students to consider other "people" who might deserve a voice: wild animals and plants, landscapes that have evolved to flux and flow, and our human descendants who will inherit our infrastructure. Whose voices have mattered most in the past, and what revisions to stakeholder influence might foster more resilient infrastructure amid climate change?

- Divide the class into three groups: **Engineers or other Physical Scientists, Ecologists**, and **Humanists or Social Scientists**. These groups represent stakeholders that need balance to achieve resilient outcomes. Review Poff's "decision scaling" and "sustainable water management systems" that "meet the needs of society over the lifetime of the infrastructure while also maintaining key ecological functions that support the long-term provision of ecosystem goods, services and values, including biodiversity maintenance. These systems would embrace the principle of resilience, that is, the capacity to persist with functional integrity under changing social and environmental conditions."
- Finish this session by presenting the groups with the real-life scenario of [Matilija Dam](). Each student already identifies as one of three stakeholder types, so they should research the dam on the website with those interests in mind. Climate scientists predict further reduction in average flow and also more variability as climate change intensifies. Their challenge is to arbitrate among three stakeholder groups of equal importance, to find the solution that increases ecological and hydrological resilience. The next session will be a [debate](). Review debate structure and have students prepare their partisan points about their stakeholder's interests.
- In the next session, convene the three-sided debate among Engineers, Ecologists, and Humanists. A notetaker compiles these arguments on the board. Each group gets an opening statement of 5 minutes that speaks specifically to **resilience** in their stakeholder perspective. (Note that resilience is not always an ecological term—it might refer to community or infrastructure.)
- Next, each group has an opportunity for a 3–5 minute rebuttal of the other groups. Finally, each group gets a 5-minute reaffirmation of their points, but they also must offer concessions to the other groups. Once this ~45-minute debate session concludes, the class reunifies to consider theses, rebuttals, concessions, and overall multi-stakeholder solutions for ~15 minutes.
- In the final 15 minutes of class or as homework, have each student write a neutral 500-word summary that equally considers all three stakeholder positions in light of the debate. Have the students submit this report for credit. The instructor could use time in the next session to review excellent reports and conclude on how decision scaling led to greater stakeholder balance and resilient remediation plans.

Background Information for the Instructor:

1. The natural flow regime: A master variable for maintaining river ecosystem health

- LeRoy Poff originally developed the concept of the natural flow regimes, which *Bioscience* published in 1997. This article provides some newer material. The significance of this particular lesson is that learners need to understand how river flow in all of its dimensions (magnitude, timing of high and low flows, frequency of floods, etc.) influence the health of rivers. Organisms, food webs, and ecosystem processes have evolved in response to these aspects of river flow (i.e., its "flow regime") and so when anything alters that (e.g., dams, climate change), the impacts vary and can be great. Flow regimes are very different in individual regions depending on the climate, geology, and land use.
- Sofi, M. S., Bhat, S., Rashid, I., & Kuniyal, J. (2020). The natural flow regime: A master variable for maintaining river ecosystem health. *Ecohydrology, 13*(8), e2247. https://doi.org/10.1002/eco.2247

2. **Ecosystem services provided by river-floodplain ecosystems**
    - This article provides an overview of the ecosystem services that are associated with river ecosystems. For learners not familiar with the categories of ecosystem services, it covers these using the definitions laid out by the Millennium Ecosystem Assessment (MEA). The MEA is considered the international authority on defining ecosystem services and has provided a wealth of documents on how to assess these. This article describes how rivers contribute to human well-being by providing "supporting services" (e.g., nutrient cycling); "regulating services" (e.g., climate regulation); "provisioning services" (e.g., food and water supply); and "cultural services" (e.g., recreation, religious services). If the instructor wants to deepen an overview on the important concepts related to ecosystem services, another useful reference is the *Intergovernmental Platform on Biodiversity and Ecosystem Services* reference book on Ecosystem Services.
    - Petsch, D. K., Cionek, V., Thomaz, S., & dos Santos, N. C. (2022). Ecosystem services provided by river-floodplain ecosystems. *Hydrobiologia*. https://doi.org/10.1007/s10750-022-04916-7

3. **Sustainable water management under future uncertainty with eco-engineering decision scaling**
    - This article is useful for instructors who wish to have learners focus on concepts associated with bridging engineering and ecological resilience to inform large water infrastructure projects. It brings to light the importance of adaptive paths in planning projects given uncertainty in future climates and social changes. For example, locking in an infrastructure project that will create hard, huge structures whose costs can only be recouped over a 50-year time span is no longer wise.
    - Poff, L., Brown, C., Grantham, T., Matthews, J., Palmer, M., Spence, C., Wilby, R., Haaznoot, M., Mendoza, G., Dominique, K., & Baeza, A. (2016). Sustainable water management under future uncertainty with eco-engineering decision scaling. *Nature Climate Change, 6*, 25-34. https://doi.org/10.1038/nclimate2765

4. **Shifting currents: Managing freshwater systems for ecological resilience in a changing climate**
    - This article summarizes how decision makers can plan and manage in ways that should promote ecological resilience. This includes a focus on managing for temporal variability, spatial heterogeneity, and hydrologic connectivity—all at the scale of whole watersheds. The authors describe a set of climate-informed ecological resilience principles and associated indicators, which they believe can support integration of ecosystem needs within water resource engineering decision making.
    - Grantham, T., Matthews, J., & Bledsoe, B. (2019). Shifting currents: Managing freshwater systems for ecological resilience in a changing climate. *Water Security, 8*, 100049. https://doi.org/10.1016/j.wasec.2019.100049

Related SESYNC Content:

- Hoover, F.A. SESYNC. (2020, November 17). *Dissecting the Decision-Making Processes Behind Green Infrastructure Siting*. YouTube. https://www.youtube.com/watch?v=06K4WXO2pUE
- Zipper, S.C., et al. (2017). Socio-environmental drought response in a mixed urban-agricultural setting: Synthesizing biophysical and governance responses in the Platte River Watershed, Nebraska, USA. *Ecology and Society 22*(4), 39. https://doi.org/10.5751/ES-09549-220439
- Cosens, B.A., et al. (2014). Introduction: The Adaptive Water Governance Project: Assessing law, resilience and governance in regional socio-ecological water systems facing a changing climate. *Idaho Law Review 51*(1). https://digitalcommons.law.uidaho.edu/cgi/viewcontent.cgi?article=1085&context=idaho-law-review
- Breyer, B., Zipper, S.C., & Qiu, J. (2018). Sociohydrological impacts of water conservation under anthropogenic drought in Austin, Texas (USA). *Water Resources Research 54*(4), 3062-3080. https://doi.org/10.1002/2017WR021155
- Cosens, B. & Gunderson, L.H. (2020). Adaptive Governance in North American Water Systems: A Legal Perspective on Resilience and Reconciliation. J. Baird & R. Plummer (Eds.), *Water Resilience* (pp. 171-192). Springer. http://link.springer.com/10.1007/978-3-030-48110-0_8

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