

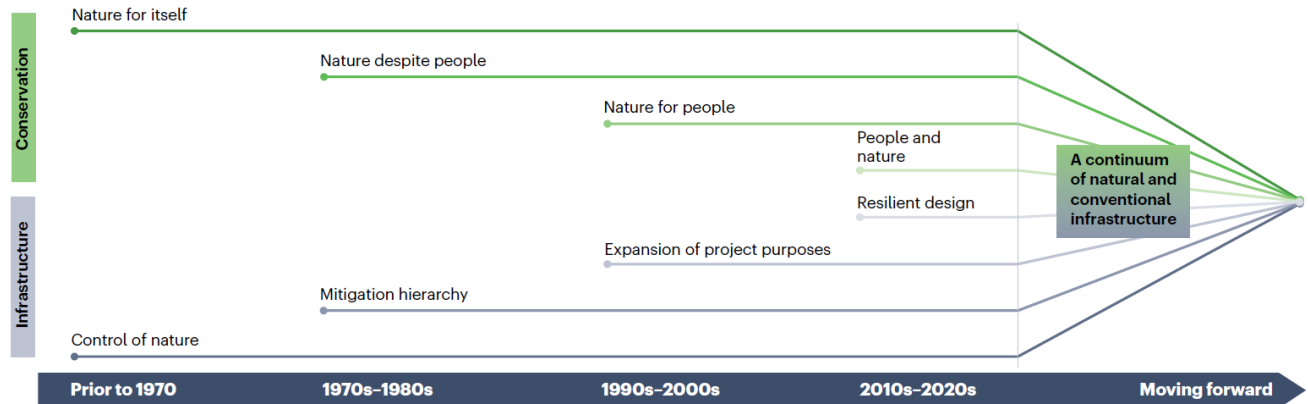
## Day 1: Handout

What do you KNOW about Natural Infrastructure?	
What do you WANT to know about Natural Infrastructure?	
What did you LEARN about Natural Infrastructure today? (end of the day)	

Themes for today:

- Overview of natural infrastructure (NI) and nature-based solutions (NBS)
- Gathering the basic terminology from physical, ecological, and social sciences.
- Developing the historical context of a system: social, physical, and ecological legacies of the past; deeper view of time; reversibility; shifting baselines.

Converging arcs of biodiversity conservation and infrastructure (McKay et al. 2023)



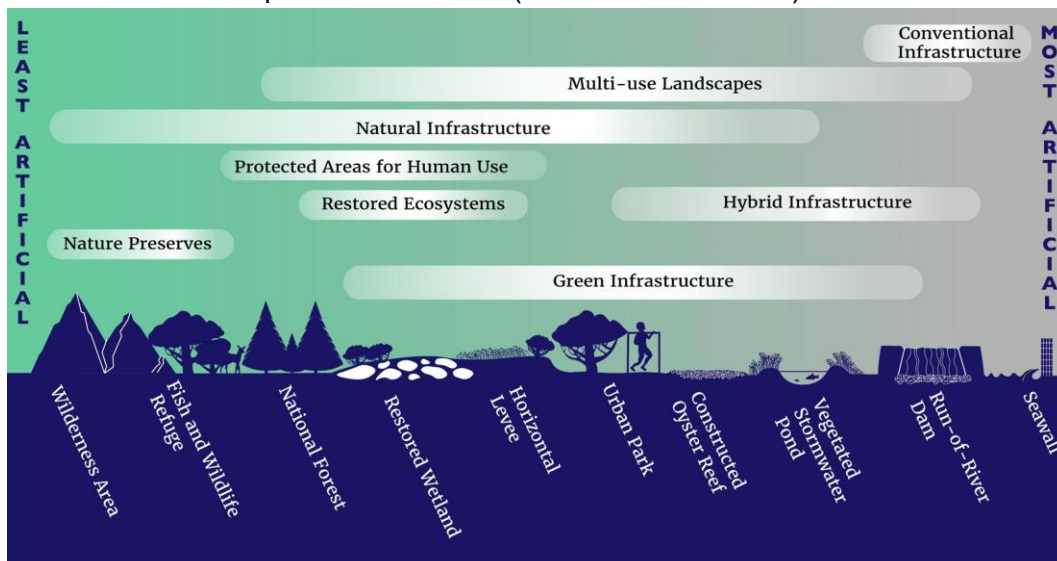
A paradigm shift is underway in the approach to planning infrastructure:

A Conventional Framing of Infrastructure	An Emergent Approach to Infrastructure
Infrastructure performs engineering functions and services	Infrastructure performs engineering functions and services
Fewer objectives centered on an organization's mission	Many objectives with a multi-purpose framing
Independent funding => independent projects	Leveraged funding => systems outcomes
Ecosystems treated as a constraint	Ecosystems included in the goals
Social benefits are happy coincidences	Social benefits are part of the design
Technical experts from a few disciplines develop alternatives	Technical experts lead alternative development, but other voices participate
<b>Typically leads to more conventional, "grey" infrastructure</b>	<b>Merges conventional infrastructure with natural systems</b>

Defining natural infrastructure

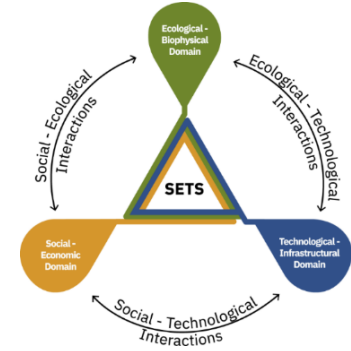
- UNEP (2022): Nature-Based Solution (NbS) are "actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services and resilience and biodiversity benefits"
- Infrastructure Investment and Jobs Act (2021): Natural infrastructure "...uses, restores, or emulates natural ecological processes...is created through the action of natural, physical, geological, biological, and chemical processes over time; is created by human design, engineering, and construction to emulate or act in concert with natural processes; or involves the use of plants, soils, and other natural features..."
- In Practice, NI is (loosely) defined by several common characteristics, not all of which may be met by any particular feature: (1) Performs infrastructure services, (2) Consists, at least in part, of natural or living materials, (3) Intentionally provides environmental and social benefits beyond typical purposes, and (4) Enhances resilience through self-adjustment.

Natural infrastructure is a spectrum of actions (van Rees et al. 2023)!



Socio-Ecological-Technical Systems (SETS figure, McPhearson et al. 2021, *npj Urban Sustainability*)

- Any view of nature-based solutions inevitably intersects social, ecological, and technical systems
- These systems have many parts, but the interactions are where the real complexity lies.

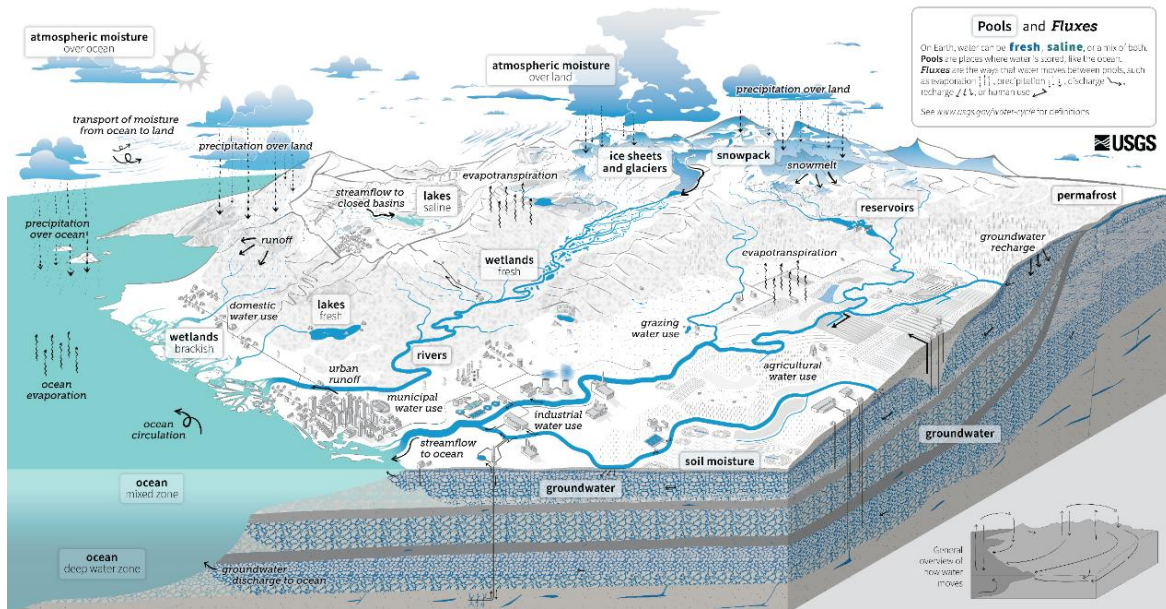


Principles of using a systems approach (de Vries et al. 2021, Chapter 4 of the International Guidelines for NNBF):

- Life safety is where flood risk management begins, but not where it ends.
- Flood risk management is nested in an interconnected socio-ecological landscape.
- Sustainable systems are resilient to disturbances.
- System-wide planning is a process worth the investment.
- Short-term benefits are balanced with long-term outcomes.

Physical systems and processes:

- Hydrology – water moving to the channel
- Hydraulics – water moving in the channel
- Fluvial geomorphology – how water shapes the earth (and how geology drives H&H)
- Biogeochemistry – the multitude of processes that affect the fate and transport of chemical constituents (and ultimately “water quality”)
- Engineering (not covered here) – uses H&H, geomorphology, and biogeochemistry to move dirt or water for a purpose.



**The Water Cycle**

The water cycle describes where water is found on Earth and how it moves. Water can be stored in the atmosphere, on Earth's surface, or below the ground. It can be in a liquid, solid, or gaseous state. Water moves between the places it is stored at large scales and at very small scales. Water moves naturally and because of human interaction, both of which affect where water is stored, how it moves, and how clean it is.

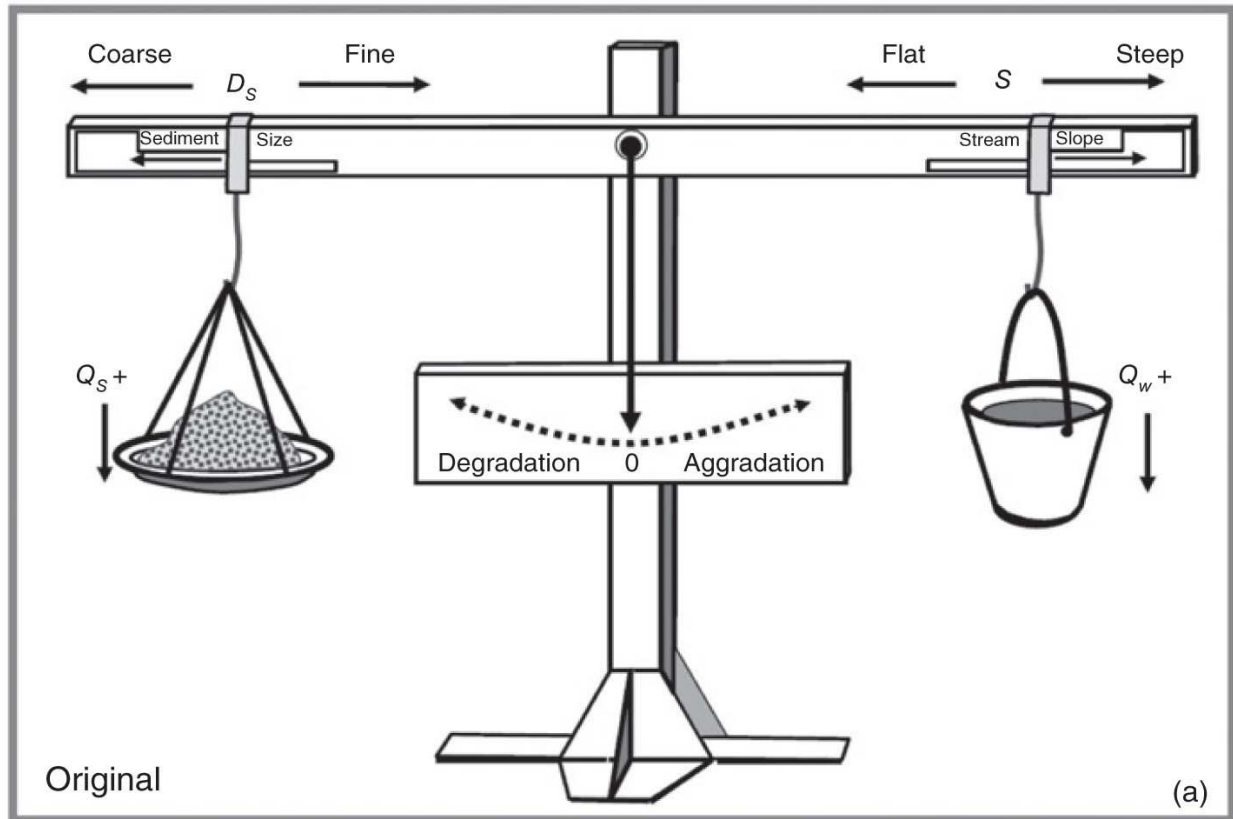
Liquid water can be fresh, saline (salty), or a mix (brackish). Ninety-six percent of all water is found in the oceans. Places like the oceans, where water is stored, are called **pools**. On land, saline water is stored in **saline lakes**, whereas fresh water is stored in liquid form in **freshwater lakes**, artificial **reservoirs**, **rivers**, **wetlands**, and in soil as **soil moisture**. Deeper underground, liquid water is stored as **groundwater** in aquifers, within the cracks and pores of rock. The solid, frozen form of water is stored in **ice sheets**, **glaciers**, and **snowpack**. At high elevations or near the earth's poles, frozen water is also found in the soil as **permafrost**. Water vapor, the gaseous form of water, is stored as **atmospheric moisture** over the ocean and land.

As it moves, water can transform into a liquid, a solid, or a gas. The different ways in which water moves between pools are known as **fluxes**. **Circulation** moves water in the oceans and transports water vapor in the atmosphere. Water moves between the atmosphere and the Earth's surface through **evaporation**, **evapotranspiration**, and **precipitation**. Water moves across the land surface through **snowmelt**, **runoff**, and **streamflow**. Through infiltration and **groundwater recharge**, water moves into the ground. When underground, groundwater flows within aquifers and can return to the surface through **springs** or from natural **groundwater discharge** into rivers and oceans.

Humans alter the water cycle. We redirect rivers, build dams to store water, and drain water from wetlands for development. We use water from rivers, lakes, reservoirs, and groundwater aquifers. We use this water (1) to supply our **homes and communities**, (2) for **agricultural irrigation** and **grazing**, livestock; and (3) in **industrial activities** like thermoelectric power generation, mining, and agriculture. The amount of available water depends on how much water is in each pool (water quantity). Water availability also depends on when and how fast water moves (water timing), how much water is used (water use), and how clean the water is (water quality).

Human activities affect **water quality**. In agricultural and urban areas, irrigation and precipitation on wash fertilizers and pesticides into rivers and groundwater. Power plants and factories return heated and contaminated water to rivers. Runoff carries chemicals, sediment, and sewage into rivers and lakes. Downstream from these types of sources, contaminated water can cause harmful algal blooms, spread diseases, and harm habitats. **Climate change** is also affecting the water cycle. It affects water quality, quantity, timing, and use. Climate change is also causing ocean acidification, sea level rise, and extreme weather. Understanding these impacts can allow progress toward sustainable water use.

Lane's Balance is a conceptual model of qualitative channel response based on Sediment load ( $Q_s$ ), Sediment size ( $D_s$ ), Discharge ( $Q$ ), and Channel Gradient ( $S$ ), where  $Q_s D_s \sim Q S$ .

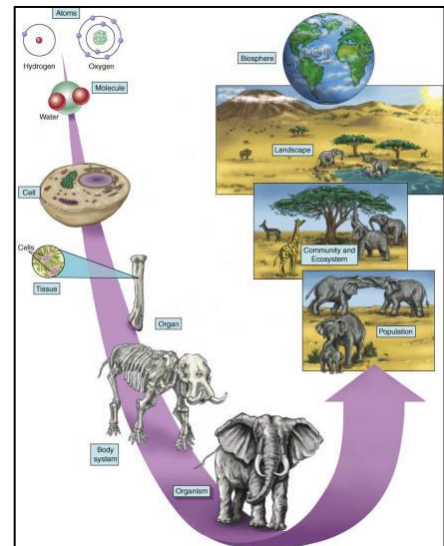


Ecosystems:

- Ecological systems are structured hierarchically.
- Population: a group of organisms of the same species occupying a particular space
- Community: a group of populations interacting in a particular space
- Ecosystem: a biotic community and its abiotic environment functioning as a system

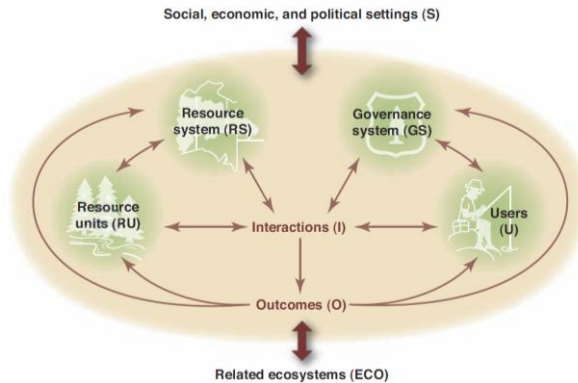
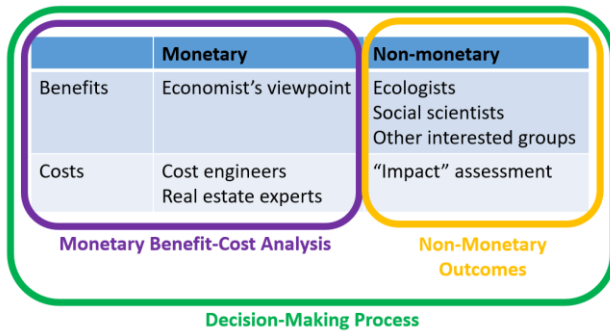
Jargon of ecological outcomes:

- Ecosystem structure: “refers to both the composition of the ecosystem (i.e., its various **parts**) and the physical and biological organization defining how those parts are organized” (Heal et al. 2005).
- Ecosystem function: “describes a process that takes place in an ecosystem as a result of the **interactions** of plants, animals, and other organisms in the ecosystem with each other or their environment” (Heal et al. 2005).
- Ecosystem service: “the benefits **people** obtain from ecosystems” (Millennium Ecosystem Assessment 2005).



A simple structure for benefits quantification

A nuanced model of common pool resource management (Ostrom 2009).



## IAP2 Spectrum of Public Participation



IAP2's Spectrum of Public Participation was designed to assist with the selection of the level of participation that defines the public's role in any public participation process. The Spectrum is used internationally, and it is found in public participation plans around the world.

		INCREASING IMPACT ON THE DECISION				
		<b>INFORM</b>	<b>CONSULT</b>	<b>INVOLVE</b>	<b>COLLABORATE</b>	<b>EMPOWER</b>
PUBLIC PARTICIPATION GOAL		To provide the public with balanced and objective information to assist them in understanding the problem, alternatives, opportunities and/or solutions.	To obtain public feedback on analysis, alternatives and/or decisions.	To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered.	To partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution.	To place final decision making in the hands of the public.
PROMISE TO THE PUBLIC		We will keep you informed.	We will keep you informed, listen to and acknowledge concerns and aspirations, and provide feedback on how public input influenced the decision.	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how public input influenced the decision.	We will look to you for advice and innovation in formulating solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible.	We will implement what you decide.

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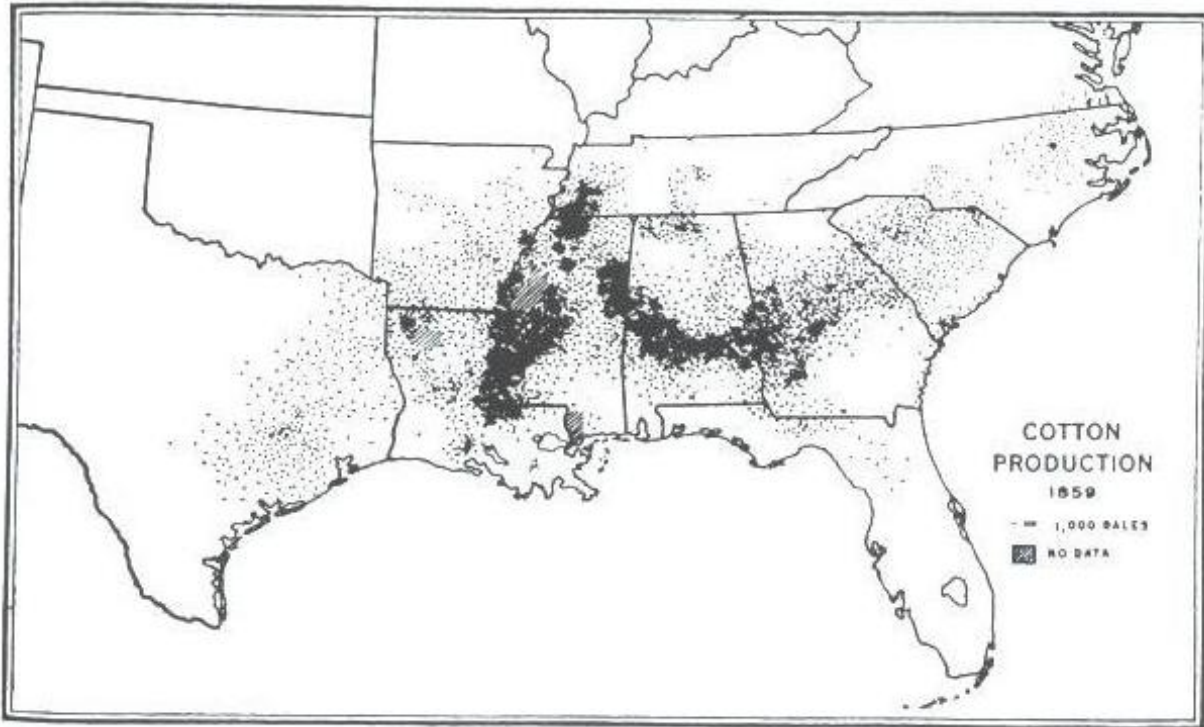


Figure: Gray (1933), Richter and Markewitz (2001)



Picture shared by Rhett Jackson

## Day 1: Exercise

### White Dam Conceptual Model

In teams of 3-4 people, develop a conceptual model of the White Dam system. The model can take any format (i.e., sketch, box-and-arrow, diagram), but it should seek to convey your understanding of the system and “tell the story” of the project. It may be constructive to use the steps for conceptual model development from Fischenich (2008). Discuss with your team how management objectives are featured in the model.

<b>Steps for Conceptual Model Development (from Fischenich 2008)</b>	<b>How you addressed them relative to White Dam</b>
1) State the model objectives.	
2) Bound the system of interest.	
3) Identify critical model components within the system of interest.	
4) Articulate the relationships among the components of interest.	
5) Represent the conceptual model.	
6) Describe an expected pattern of model behavior.	
7) Test, review, and revise as needed.	