

# **Glen Canyon Dam Simulation**

**Lesson created by  
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based on a simulation originally created by Frank  
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# Glen Canyon Dam Simulation

**Grade Level:** 7th grade

**CFSD Curriculum:** Earth Science

**Lesson Objectives:** To describe some of the factors to be considered when regulating water from Glen Canyon Dam.

**Systems Concept(s):** patterns over time, interdependencies, tradeoffs, competing goals

**Systems Tool(s):** behavior-over-time graphs (BOTGs), computer simulation, stock/flow maps

## **Activities at a Glance:**

- Students are introduced to the area of Glen Canyon Dam. Various activities can be used including reading an article or viewing a video.
- Students use a simulation to assume the role of operating Glen Canyon Dam in Arizona. They must decide how much water to release through the dam over time. Prior to deciding, the students read information about how much water is necessary to keep different local interest groups (anglers, rafters, and power company employees) happy with the water flow. The students adjust the water released based on feedback they receive from these three groups. This feedback takes the form of complaints when the water flow does not match their needs.
- After running the simulation, students discuss their results in class to analyze the effects over time of various strategies used.

## **Time Allotment:**

Introduction: - one -two periods

Simulation - three periods

Debrief - one period

## **Integration Area(s):**

**Social Studies -** Students could study the many issues of providing electricity for the general public as well as maintaining the environment and keeping the recreational users happy.

**Math -** Students could look at the actual calculations of how much electricity is produced based on the amount of water flowing through the dam.

**Writing/Literature:** Students could write letters to their local congressman or to an environmental group to make a recommendation for managing Glen Canyon Dam and the water flow through the Colorado River.

## **Materials Needed For Lesson:**

### **Materials:**

- paper & pencils
- chalkboard & chalk
- article (see sources for examples) about a current issue surrounding Glen Canyon Dam. (optional)
- handouts (1 per student): “Computer Activity: The Glen Canyon Dam Controversy” (see attached)

**Media:**

- STELLA 5.0 software
- Glen Canyon Dam 5.0 simulation
- overhead transparencies of the debrief BOTGs for the three scenarios (see attached)
- Video - (see sources for examples) (optional)

**Equipment:**

- TV/VCR (optional)
- color Macintosh computers (one computer per two students)
- overhead projector

**Preparation:**

- Copy student handouts
- Locate and copy article (optional)
- Locate video (optional)
- Install STELLA software and simulation
- Assign students to partners

**Activity(ies):****Introduction**

- Have a classroom discussion about the purpose of a dam.
- Show students the location of Glen Canyon Dam on a map.
- Discuss some of the current issues surrounding the operation of the dam. One of these might be the conflict between the power company that wants to provide a reliable source of power and the people who want to use the Colorado River and Grand Canyon area as a source of recreation.
- Introduction Option 1 uses an article and BOTGs to increase student understanding of the purpose of the dam and its effect on the environment over time.
  - Introduce or review BOTGs (See tips for BOTGs - attached)
  - Give students an article to read about Glen Canyon Dam and have them generate BOTGs from the article. Before they start reading, suggest that they should think about what is changing over time.
  - As a class, brainstorm a list of variables changing in the article.
  - Have students work in small groups to generate at least three BOTGs.
  - Have some students share their graphs on the board and explain the patterns.
  - Explain that when running the computer simulation, students will want to notice and think about any patterns that are occurring.
- Introduction Option 2 uses a video that describes the area and recent issues surrounding the dam:
  - Show the video and discuss the key components.
  - If desired, have students graph using BOTGs in a similar way as with the article above.

**Computer Lab**

- Have students open the simulation.
- Explain the following to students about running the simulation and completing their packets:
  - They will be in charge of operating Glen Canyon Dam.
  - Their job will be first to understand some of the issues surrounding the dam and then to operate the dam in such a way that will make all the interest groups happy.
  - Read together the objective and procedure on the first page of the handout.

- They should discuss and make decisions together with their partners, but each individual is accountable for completing the packet. Answers should fully explain their ideas.
- Read the packet and follow the directions carefully. Sometimes they will be asked to make predictions BEFORE running. It is important to make the prediction FIRST. They will not be graded on the correctness of the prediction, but rather on the completeness of their explanations.
- Students work with their partner to complete their packet. The teacher can answer questions as necessary.

### **Debrief:**

- Option 1:
  - As a class, discuss what was learned in the simulation.
  - As a class, draw a stock/flow map making connections based on what the students understood of the system in this simulation. (see tips for stock/flow maps). Accumulations could include angler complaints, rafter complaints, and power complaints. Through this process, the teacher can check for the students' understanding of the interdependencies between the parts of this particular system.
- Option 2: Have a class discussion as described below. You can create overhead transparencies of the three scenarios to use as visuals during the discussion (see attached).
  - Were you able to make every group completely happy? Why or why not?
  - Have students share some of their responses from question 12.
  - What is a competing goal? Talk about competing goals and how difficult or even impossible it is to meet several different goals.
  - Talk about how any action has associated benefits and tradeoffs. In the simulation, as you were trying to meet the goals of the different groups, each action that you took, had some benefits and some tradeoffs for various groups.
  - Show the three scenarios one at a time and have students generate benefits and tradeoffs for each one. See examples below. Discuss why some of the tradeoffs might become serious problems in the long term. e.g. If the dam operator is not generating enough power, then he/she could be fired; if there are too many problems for rafters/anglers, they might go out of business or move their business elsewhere which could affect the economy.

- **Scenario 1: Set to a flow based on average demand and keep the flow as steady as possible**

**Benefits**

- Able to meet most power needs
- No complaints from river rafters
- Very few complaints from anglers
- Safe conditions for river rafters

**Tradeoffs**

- Sometimes fall short on meeting power demands
- Not able to sell electricity at top price
- Somewhat more difficult fishing

- **Scenario 2: Meet the power demands of the day/week as they arise**

**Benefits**

- Able to meet all power needs
- Able to sell electricity at top price

**Tradeoffs**

- Many complaints from river rafters
- Many complaints from anglers
- Dangerous conditions for river runners
- Unpredictable water conditions for anglers

- **Scenario 3: Crisis Management; Respond to complaints as they arise**

**Benefits**

- Able to meet most power needs
- Everyone happy some of the time

**Tradeoffs**

- Some dangerous conditions for river rafters
- Some complaints from anglers

- What strategy did you find to be most successful, that is, with which one were you able to meet the needs of most groups most of the time?
- Tell the students that in the next week they will be researching various issues surrounding the dam, creating a plan, and defending that plan through a debate. As they are doing this they might want to consider the possible benefits and tradeoffs that their policy might have.
- In addition they should remember that the simulation was meant to help them begin to see some of the interdependencies and dynamics involved in operating Glen Canyon Dam. The specific data in the simulation is not meant to be used as proof in their debate. That info will need to be obtained from specific current data on the dam.

**Assessment:**

Students are graded on the packet they complete while they are going through the simulation. They are also given points for participation during all class discussions.

**Sources:**

For introduction option 1, articles were obtained from the newspaper, The Arizona Daily Star. Although using more current articles is desirable, some older examples are:

“Artificial Flooding Plan at Canyon is Delayed” The Arizona Daily Star (AZ). 5 January 1995. B1.

“Comes the Flood” The Arizona Daily Star (AZ). 27 March 1996. A10.

Boorstein, Michelle. “Squeezed, Corralled, Colorado River Demanding to be Protected” The Arizona Daily Star (AZ). 25 May 1997. B1.

Although too long for a brief introduction, another interesting article that gives background information and some of the controversy surrounding the area is:

Long, Michael E. “Grand Managed Canyon.” National Geographic. July 1997: 117-135.

A book with some different perspectives on the controversies surrounding the building of dams is:

McPhee, John. Encounters with the Archdruid. Farrer Straus Giroux. 1989

For introduction option 2, two video options are listed below. They would take longer than one period, so the introduction would need to be extended.:

The Desert Speaks #713 - Grand Canyon Flood! Video. KUAT Communications Group, University of Arizona, Tucson, AZ. 85721. ©1997 - Arizona Board of Regents. 57 minutes

The Cadillac Desert - Episode 2: An American Nile Video. KTEH, San Francisco, CA.  
[www.kteh.org/cadillacdesert/home.html](http://www.kteh.org/cadillacdesert/home.html)

**Extension(s):**

After the simulation the students do library research and take part in debates that not only deal with the issues within the simulation, but also with larger-scale issues involved in the use and development of Grand Canyon National Park.

Name \_\_\_\_\_

Teacher \_\_\_\_\_ Per. \_\_\_\_\_

Date \_\_\_\_\_

## COMPUTER ACTIVITY: THE GLEN CANYON DAM CONTROVERSY

**Objective:** To describe some of the factors to be considered when regulating water from Glen Canyon Dam.

### **Procedure:**

Whenever you see an underlined title below, select that title on the computer screen by clicking on it. Answer the questions for each selection after you have read the information on the computer screen.

### **Click on Start**

#### **1. Click on Introduction**

a. What are some of the duties of the National Park Service?

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b. What are some of the duties of the Bureau of Reclamation?

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#### **2. Click on Map**

a. Click on Glen Canyon Dam

a.1. Where is Glen Canyon Dam?

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a.2. Why was Glen Canyon Dam built?

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a.3. Explain how hydroelectric power is generated.

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**Click again on "Glen Canyon Dam" to remove the paragraph from the screen.**

**b. Click on Colorado River**

b.1. How has Glen Canyon Dam changed the Colorado River?

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b.2. List 2 reasons why people visit the Colorado River.

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**Click again on "Colorado River" to remove the paragraph from the screen.**

**c. Click on Lake Powell**

c.1. Explain how Lake Powell was made. (Note: This is a "thought" question. You will not find the answer on the screen.)

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**Click on Menu**

**3. Click on Dam Operator**

a. What is the job of the dam operator?

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b. Explain how the dam operator's job affects the amount of electricity generated.

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**4. Click on See Sample Electricity Demand**

a. Why does the demand for electricity fluctuate so much during the week?

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**Click on Return**

**Click on Menu**

5. Click on Anglers (Trout Fishermen)

- a. List several reasons why fishermen are concerned about the flow of the Colorado River.

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- b. The flow of water in a river is described in units of cubic feet per second (cfs). (It is determined by multiplying a river's width X depth X average velocity). What is the optimum flow of the Colorado River for the fishing industry?

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Click on Menu

6. Click on Rafters (River Runners)

- a. What happens to the Colorado River when its level fluctuates rapidly due to changes made by the dam operator?

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- b. What is the optimum flow (in cfs) of the Colorado River for the rafting industry?

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Click on Menu

7. Click on Start Simulation

- a. You can select a variety of items on the computer screen and read about them before you actually do the simulation.

Click on the following items:

Megawatt Demand & Megawatts Generated

Low Power Generation

Rafters' Complaints

Anglers' Complaints

Release in Thousands of CFS

Day of week

Hour

Click on Graphs

8. Predictions

- a. Click the black dynamite stick on each graph to clear any previous graphs.
- b. You are the dam operator. Your goal is to make the anglers and rafters happy, keeping their complaints low, while supplying enough electricity to meet power demands. Remember, producing too much electricity can cost money. **Graph your plan for release of water below to accomplish that goal.** To do this, move your mouse so the hand is directly over the graph. Hold down the mouse button and drag until the line matches your plan. **Now graph what you think will happen to rafters' and anglers' complaints.**

Explain below why you chose this plan and how you intend to achieve it. Talk about the actual amount of water in CFS that you will release. **Copy your predictions as dotted lines on the graphs below.** Note: You do not need to predict on the Megawatt graph.

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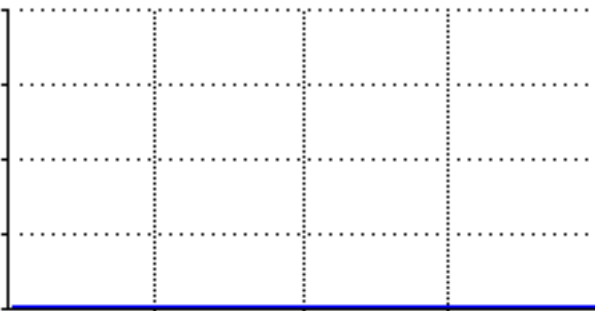
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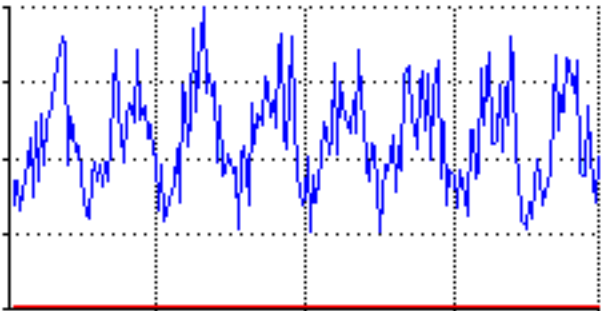
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Release of Water



Megawatt Demand/Megawatts Generated



Rafters' Complaints



Anglers' Complaints





9. Click on Start Simulation

- a. Set the value for the release of water from Glen Canyon Dam to match your plan.
- b. Running the simulation: As the simulation is running, watch the bar graph showing megawatt demand/megawatts generated. Also watch the warning flashers on the right side of the screen to see if any group becomes unhappy with the flow conditions. Adjust your flow values as necessary.  
Click on Run. NOTE: You may pause the simulation at any time to discuss strategies with your partner. Click the run button again to continue.

10. Click on Graphs

- a. Copy the graphs onto the previous page using solid lines.
- b. Based on what you observed during the simulation and the graphs, check which groups were unhappy or happy with the water flow conditions you selected and explain why.

Group			Why?
Rafters			
Anglers			
Power Company			

11. Why was what actually happened different from your predictions? Look at the graphs.

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**Scenario 2: Meet the power demands for each day as they go up and down. Watch the demand bar graph and adjust the flow accordingly.**

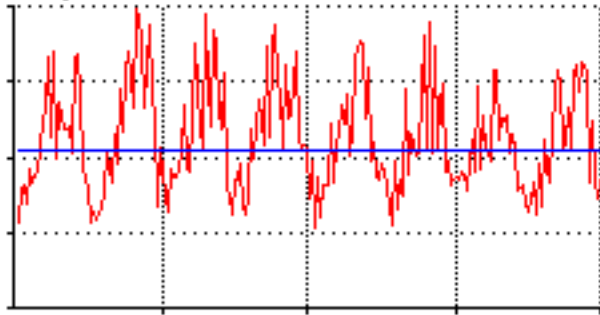
<b>Group</b>			<b>Why?</b>
<b>Rafters</b>			
<b>Anglers</b>			
<b>Power Company</b>			

**Scenario 3: Crisis Management; Adjust the flow based on complaints as they arise.**

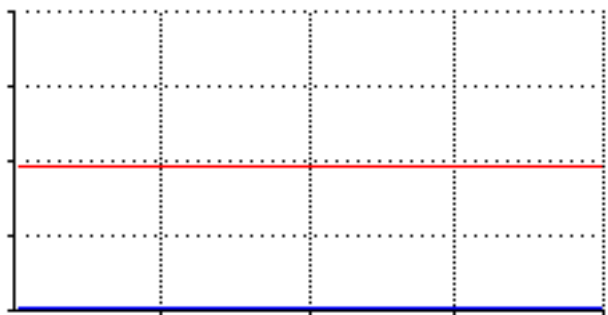
<b>Group</b>			<b>Why?</b>
<b>Rafters</b>			
<b>Anglers</b>			
<b>Power Company</b>			

**Scenario 1: Set to the best flow based on average demand and keep the flow as steady as possible**

Megawatt Demand and MW Generated



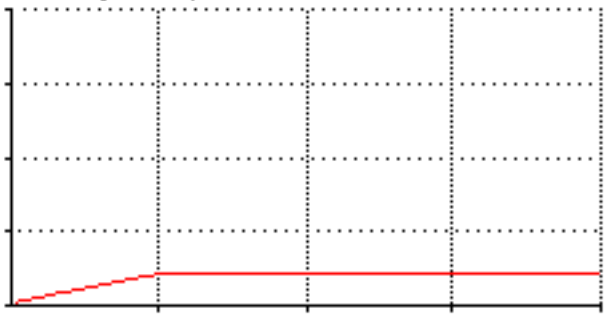
Release of Water



Boating Complaints



Fishing Complaints

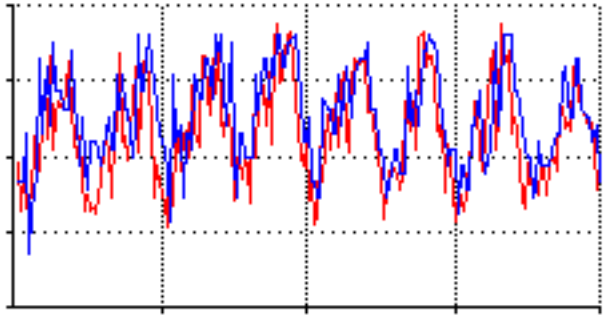


**Benefits**

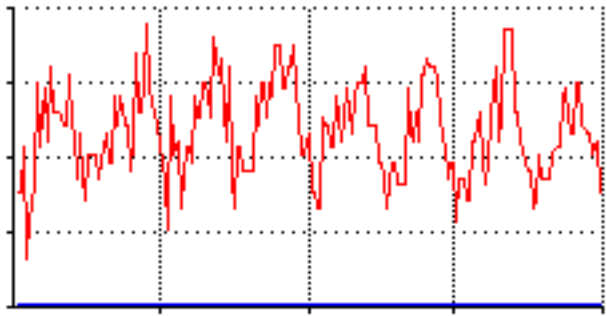
**Tradeoffs**

**Scenario 2: Meet the power demands of the day/week as they arise**

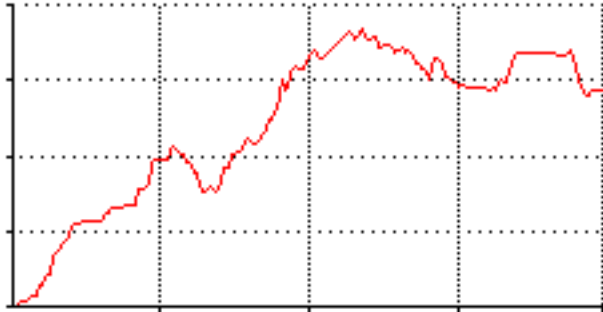
Megawatt Demand and MW Generated



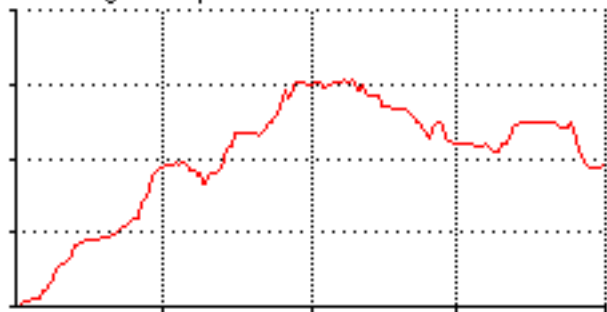
Release of Water



Boating Complaints



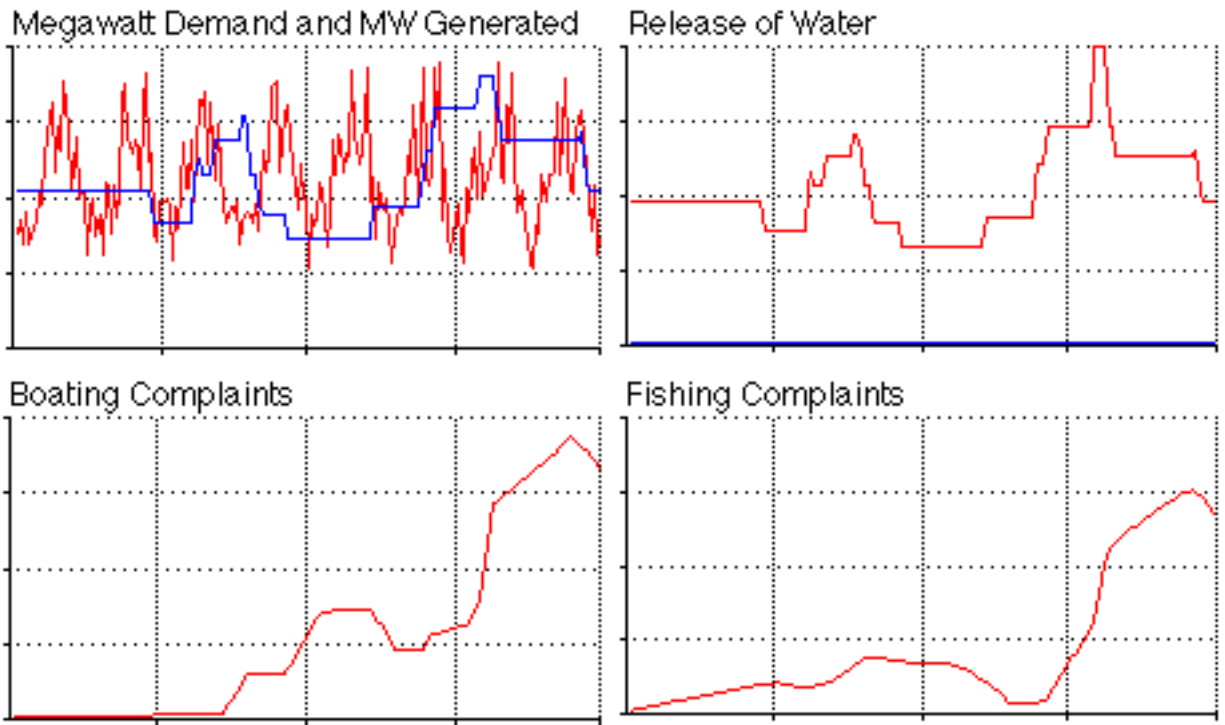
Fishing Complaints



**Benefits**

**Tradeoffs**

**Scenario 3: Crisis Management; Respond to complaints as they arise**

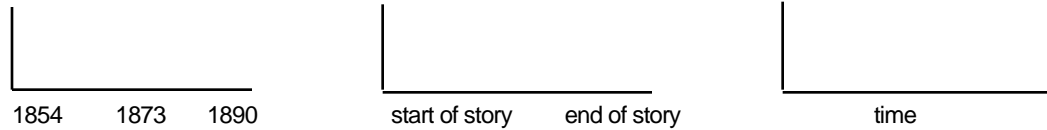


Benefits

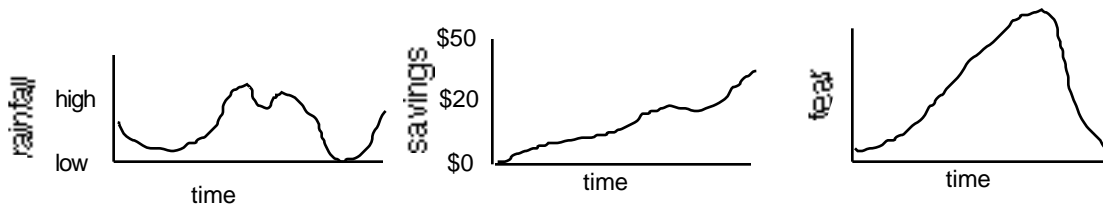
Tradeoffs

## Tips for Behavior-Over-Time-Graphs (BOTGs)

1. A BOTG shows the trend, or pattern of change, of a variable over time as opposed to discrete events.
2. On a basic line graph that is a BOTG:
  - the X axis is always labeled time
  - the X axis' beginning, medial, and ending times may be indicated or not, depending on your purpose:



3. The Y axis:
  - indicates the variable being graphed and must be labeled with that variable's name
  - label is particularly important when looking at graphs of different variables
  - should not include qualitative words such as more, less, increasing, bigger, etc. in the variable's name; it's difficult to understand less "More fear" over time
  - variable being graphed may be "hard" (like population or temperature) or "soft" (like love or stress)
  - may be quantified as much or little as possible, or not at all:



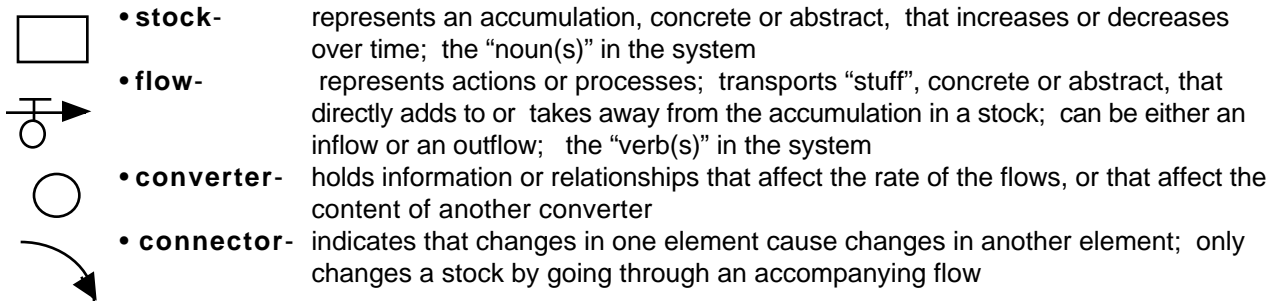
4. If students/staff choose to graph more than one variable on the same graph, they will need to differentiate between the lines on the graph by including a key of some sort.
5. Different interpretations of the stated variable are definitely possible, although generally peoples' graphs of the same variable will look fairly similar. If they are radically different, discussion of the differences should take place, and could be very interesting!
6. Discussion of when and where a trend or pattern of behavior starts, ends, or changes direction is recommended.
7. When discussing the graphs of different variables, the graphs could be compared for possible interdependencies and causal relationships between the variables.

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## Tips for Stock/Flow Diagrams/Maps

1. **Stock/Flow Diagrams or Maps** show interdependencies and feedback within a system by identifying major accumulations and the factors that increase and decrease them over time.

2. Definitions:



3. Depending on the group, you may want to explain and draw this “bathtub analogy” before mapping:

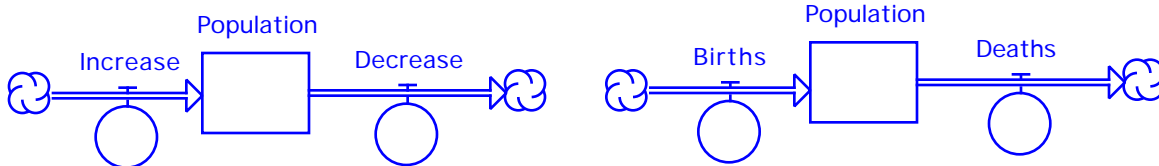
- a stock is like a bathtub which can be filled or drained
- an inflow is like a pipe that goes into the stock (tub) and fills it according to how much the spigot on the pipe (inflow) is opened/closed
- an outflow is like the drain that allows the accumulation to flow out according to how much the drain spigot (outflow) is opened/closed
- a converter is like a wrench that adjusts the spigot on a flow by way of the connector

4. For group mapping, you may choose to draw the map freehand and display it, or use the STELLA program and project it.

5a. One way to generate possible **stocks** to use in a map is to have the group create and discuss BOTGs from the article/story/information under consideration, then choose the BOTG(s) they wish to study as the stock(s) in the map (perhaps the most important accumulations). \*

b. Another way is simply to choose the stocks you wish to emphasize ahead of time, making sure at some point to have the group create the BOTG that represents the trend of each stock’s accumulation/drain over time.

6. The **inflow** and **outflow** can be labeled simply as “Increase” and “Decrease” or as concrete or abstract “stuff” flowing into and/or out of the stock. The unit of measure used for the stock must also be used to measure the inflow and outflow. Remember: if you stop time in the system, nothing will remain in the flows, but the accumulation will remain in the stock.



7. **Converters** may be chosen from the remaining BOTGs generated in 5a above, or directly from the article/story/information. It is sometimes helpful to aggregate information in converters, e.g. tornado, fire, flooding, and earthquake could be aggregated in a converter labeled “natural disasters.”

8. A **connector** must point to the element that is being affected.

9. Once you have set up your stock(s), flows, converters, and connectors, make sure you look for the **feedback** that makes a system dynamic! Ask questions such as: Does the accumulation in the stock affect its inflow? outflow? converters? other stocks’ inflow/outflow/converters?

\* When choosing a name for any element in a S/F map, try to keep words like “more” and “less” out of the name; e.g. “Level of Stress” is preferable to “More Stress”.