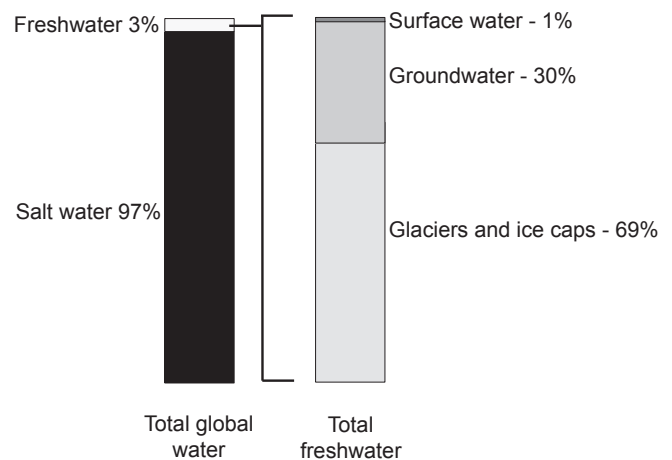


Lab Handout**Lab 23. Human Use of Natural Resources: Which Combination of Water Use Policies Will Ensure That the Phoenix Metropolitan Area Water Supply Is Sustainable?****Introduction**

Water is an essential resource for us. We must drink water to survive. People also use water to cook, to clean, and for recreational purposes. We also need water to grow the food that we need and to produce many of the products that we use on a daily basis. Many people think water is an unlimited resource because oceans cover about 70% of Earth's surface. The water found in oceans, however, is high in salt and not fit for human consumption. In fact, 97% of the water found on Earth is classified as salt water (see Figure L23.1), so only 3% of all the water found on Earth is fresh. Of all this freshwater, about 69% of it is frozen in glaciers and the ice caps, 30% is groundwater, and the remaining 1% is located on the surface in lakes, rivers, marshes, and swamps. All our drinking water and the water we use for agriculture, manufacturing, and sanitation comes from this relatively small amount of surface water and groundwater.

Water reservoirs include natural or human-made lakes (see Figure L23.2, p. 544) and the groundwater that is found in large aquifers, which are underground stores of freshwater (see Figure L23.3, p. 544). Scientists use the term *recharge* to describe how a reservoir fills with water over time. The rate of recharge depends on the amount of precipitation that happens in an area. Many people depend on an aboveground and/or belowground water reservoir to supply all the water they use on a daily basis. Unfortunately, a water reservoir can be depleted of water faster than it can recharge when people consume too much water and there is not much precipitation in an area for an extended amount of time. When a water reservoir runs dry, people who live in that area are forced to do without the water they need until it fills again. High consumption of water can also have a negative impact on the local environment. Typically, as human population and per capita (per person) consumption of water in a region increases, so does the likelihood that the people and the environment in that region will experience a negative impact. It is therefore important for people in a region to find a way to use water in a sustainable manner.

FIGURE L23.1**Distribution of water on Earth**

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FIGURE L23.2

The Lake Mead Reservoir in Nevada and Arizona

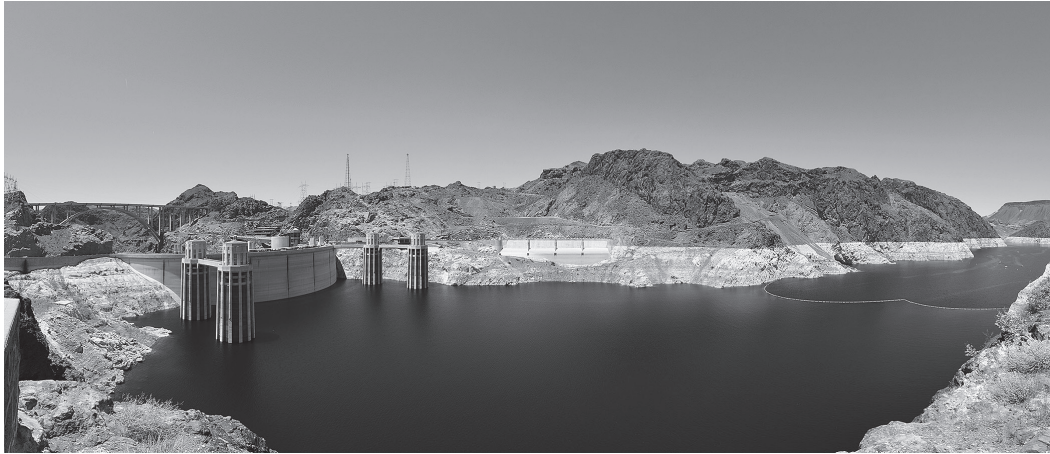
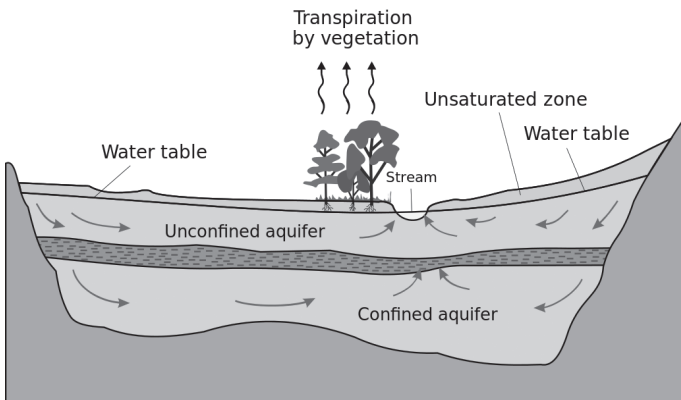






FIGURE L23.3

Illustration of an aquifer



-  High hydraulic-conductivity aquifer
-  Low hydraulic-conductivity confining unit
-  Very low hydraulic-conductivity bedrock
-  Direction of ground-water flow

One way that a group of people can ensure that their use of water over time is sustainable is for them to establish and then follow policies that will always keep the amount or rate of water use (*demand*) at a level that is equal to or below the amount of water that is or will be available in the local water reservoir (*supply*). The state of Arizona is a good example of how people can work together to ensure that their consumption of water is sustainable over time despite having a limited supply

Arizona is one of the driest states in the United States. In fact, it only receives a state-wide average of 12.5 inches of rain per year. Arizona is also one of the fastest-growing states in terms of population. Arizona's population in 2010 was 6.4 million and is projected to increase to over 9.5 million people by 2025 (U.S. Census Bureau 2012). Most of the people who live in Arizona reside within the Phoenix metropolitan area (PMA). The population in the PMA in 2010 was about 4.2 million (U.S. Census Bureau 2012). This many people living in the same area can use a lot of water over the course of a year. In fact, people living in the PMA used 3,667 acre-feet (1 acre-foot = 325,851 gallons) of water in 2008 (Arizona

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Department of Water Resources [2009]). The dry climate presents numerous challenges for the people living in Arizona because they can quickly deplete their limited water supply. Therefore, the people of Arizona must find sustainable ways to use their limited supply of water to ensure that they can maintain their quality of life and grow their economy without damaging the local environment.

The people of Arizona get the water they need for agriculture, industry, and municipal use from three major sources. *The first major source is surface water*, and the largest portion of surface water comes from two main reservoirs on the Colorado River (Lake Mead and Lake Powell). The Colorado River starts in the central Rocky Mountains and drains into the Gulf of California (see Figure L23.4). The Colorado River supplies water to people in Arizona, California, Nevada, New Mexico, Utah, Colorado, Wyoming, and Mexico.

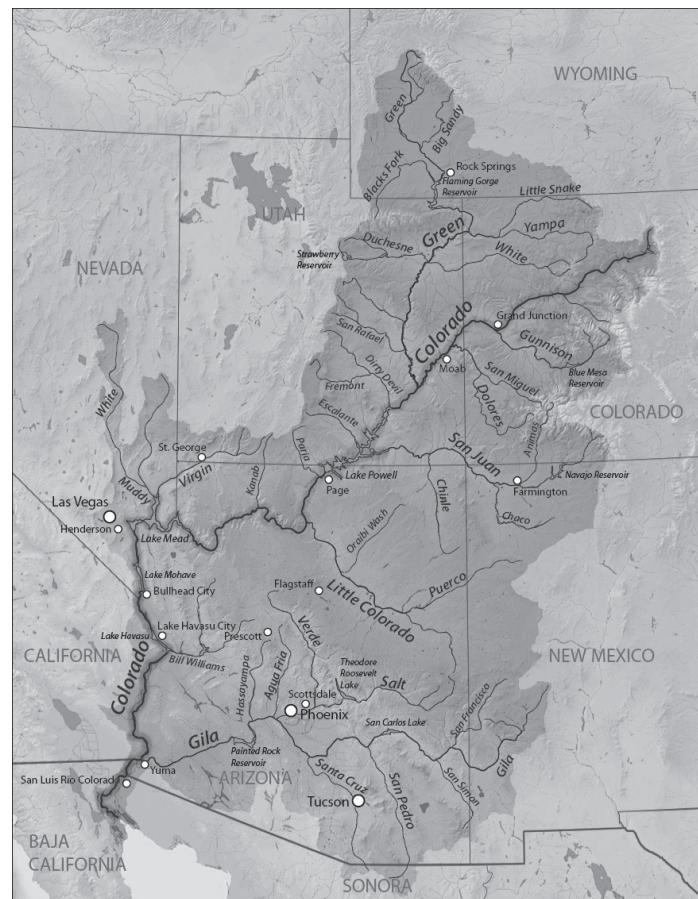
The people of Arizona are only allowed to take 2.8 million acre-feet of water from the Colorado River reservoirs annually (Arizona Department of Water Resources n.d.).

Smaller rivers and lakes in Arizona also provide some water for the people of Arizona. However, the amount of water available from these sites varies from year to year, season to season, and place to place because of the desert climate. The Arizona government has therefore built reservoir storage systems in most of the major rivers within the state, such as the Salt, Verde, Gila, and Agua Fria.

The second major source of water is groundwater. Aquifers supply about 43% of the state's water (Arizona Department of Water Resources n.d.). Throughout the 20th and 21st centuries, however, groundwater has been pumped out of the aquifers faster than it could recharge, which has left them depleted. Though a large amount of water remains stored underground, its availability is limited.

FIGURE L23.4

A map of the Colorado River watershed



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The third major source of water in Arizona is effluent. Effluent, or reclaimed water, is wastewater that has been collected and treated. The people of Arizona use reclaimed water for agriculture, golf courses, industrial cooling, and to maintain parks and other wildlife areas.

To help the people of the PMA identify and enact policies that will ensure that the available water supply is used in a sustainable manner, scientists at Arizona State University created a visualization tool called *WaterSim*. *WaterSim* uses a mathematical model to estimate water supply and demand for the PMA. People can use the *WaterSim* visualization tool to explore how various regional population growth, drought, and climate change scenarios and water management policies affect water sustainability. This visualization tool is valuable because it takes a lot of data that are usually collected separately (including water supply, water demand, climate, population, and policy data) and puts them together to give the user a way to see how all these different variables interact with each other. It also allows a user to change one variable in the system at a time and see how that change affects the other components of the system. In this investigation, you will have an opportunity to use the *WaterSim* visualization tool to explore different water use policies to determine how these different policies, if enacted, will affect the sustainability of the PMA water supply.

Your Task

Use what you know about natural resources, human impacts on Earth systems, stability and change, and cause-and-effect relationships to determine how different water use policies will affect the current and near-future needs of the people living in the PMA. To accomplish this goal, you will need to use the *WaterSim* visualization tool to examine how different water use choices will affect the water supply between now and the year 2050, assuming best- and worst-case scenarios for population growth, drought, and climate change. Your analysis, at a minimum, will need to examine per capita water use, the percentage of wastewater to be reclaimed, and the percentage of farm water to be used by cities in the PMA. It should also include an analysis of how much of the water in the Colorado River can be used to help restore the Colorado River delta of northern Mexico to prevent future habitat and biodiversity loss.

The guiding question of this investigation is, *Which combination of water use policies will ensure that the Phoenix Metropolitan Area water supply is sustainable?*

Materials

You will use a visualization tool called *WaterSim* to explore how water policy decisions influence water supply and sustainability; the tool is available at <https://sustainability.asu.edu/dcdc/watersim>.

Safety Precautions

Follow all normal lab safety rules.

Investigation Proposal Required? Yes No

Getting Started

You can use the *WaterSim* visualization tool (see Figure L23.5, p. 548) to examine how different water use choices affect the sustainability of water in the PMA over time, assuming different conditions in Arizona. This tool is useful because it allows users to see and understand the gap between a proposed policy choice (such as the percentage of wastewater to be reclaimed or how much farm water should be diverted to cities) and what actually needs to happen to ensure the sustainability of a water supply. *WaterSim* therefore offers you a way to test different policies.

The first step in this investigation is to develop an overall water use plan for the PMA and then see how this plan will affect the sustainability of water over time. *WaterSim* allows you to create a water use plan for the PMA that includes the following policy choices:

- the amount of total wastewater from residential, commercial, and industrial water users that is diverted to the reclaimed wastewater treatment plant (“% of Wastewater Reclaimed”);
- the agriculture (farming) water made available for urban water use (“Farm Water Used by Cities”);
- the portion of the Colorado River water flow intentionally left in the river to be diverted for use by the Colorado River delta (“Environmental Flows”); and
- the amount of water that people use at home, which is measured in units of *gallons per capita per day* (GPCD) per person (“Per Capita Water Use”)

You can set values for these four water use policy choices using the sliders in the lower-left corner of the simulation.

Next, you can examine how these choices will affect the sustainability of the PMA water system using five different indicators at the top of the simulation. Each indicator represents a different aspect of water sustainability:

- *Groundwater*. How much groundwater needs to be extracted from the aquifers to meet the demands of the community as a percentage of the total amount of water use.
- *Environment*. The percentage contribution of Arizona’s commitment to leave water in the Colorado River to restore the Colorado River delta
- *Ag to Urban*. The amount of agriculture water credits being diverted from farming and agriculture for municipal water use. Agriculture is a major part of the economy in Arizona, so less water available for agriculture means less economic growth.
- *Personal*. The amount of water that can be used for people to cook, clean, bathe, dispose of waste, and irrigate yards. Water is needed for health, comfort,

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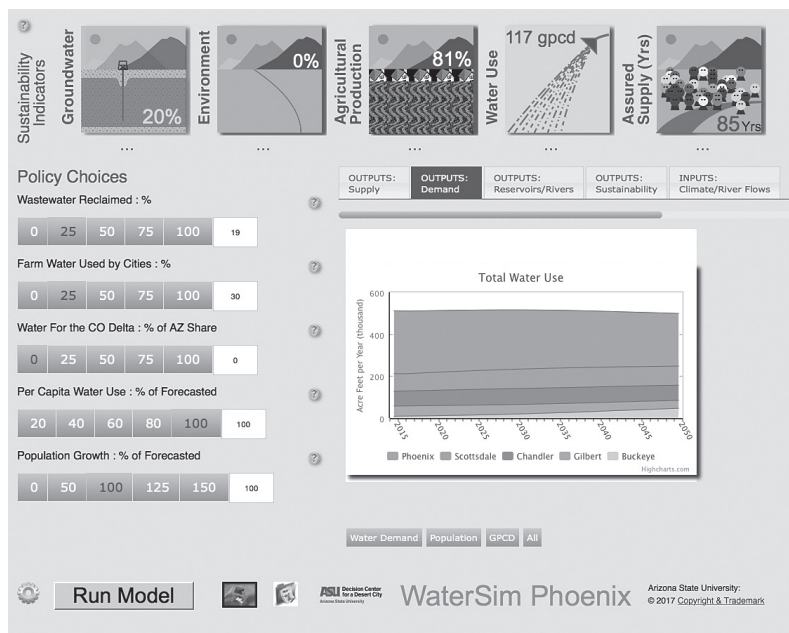
and overall well-being, so less water available for personal use means more inconveniences for people.

- *Population.* How many years the water supply can support the current population before the population would experience water deficits or, alternatively, have to find more water at a higher cost.

The value presented inside the box for each indicator represents the final value (end of 2050) over the simulation period. The values for each indicator from the previous simulation are retained at the bottom of each indicator (in parentheses).

FIGURE L23.5

Screenshot of the *WaterSim* visualization tool



Once you have identified an overall water use plan for the PMA and determined how it will affect water sustainability over time, you can then begin to modify each water use policy choice to make the overall plan more effective. You can also change how fast the population will grow over time, how often and how long droughts will occur, and how the climate may change over time in the *WaterSim* visualization tool. Your goal for this step of the investigation is to determine how different policies will need to be modified to close the gap between what is proposed and what actually needs to happen to ensure the sustainability of the PMA water supply. As you modify the different water use policies and your assumptions about population growth, droughts, and climate change in the *WaterSim* visualization tool, think about the following questions to help guide the changes you will make:

Which Combination of Water Use Policies Will Ensure That the Phoenix Metropolitan Area Water Supply Is Sustainable?

- What are the components of the system and how do they interact with each other?
- When is this system stable and under which conditions does it change?
- Which factor(s) might control the rate of change in this system?
- What scale or scales should you use when you take measurements?

The last step in your investigation will be to identify the potential challenges and consequences that are associated with putting a proposed water use plan into action. This is important because policies affect the lives of people. For example, what are the consequences to farmers of a policy that requires more water to be diverted from farms to cities? Will farmers lose their jobs or their land? What will this do to the overall economy? You must also consider what is ethical and what is fair in terms of any proposed policy. For example, does a policy impact the people who live in cities and in rural areas the same way? You will need to take these issues into account to ensure that your proposed water use plan is valid and acceptable. You can include information about any political, economic, or social issues you considered as you developed and evaluated your policy as part of your justification of your evidence.

Connections to the Nature of Scientific Knowledge and Scientific Inquiry

As you work through your investigation, be sure to think about

- how scientific knowledge can change over time, and
- the types of questions that scientists can investigate.

Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your initial argument needs to include a claim, evidence to support your claim, and a justification of the evidence. The *claim* is your group's answer to the guiding question. The *evidence* is an analysis and interpretation of your data. Finally, the *justification* of the evidence is why your group thinks the evidence matters. The justification of the evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard. Your whiteboard should include all the information shown in Figure L23.6.

Argumentation Session

The argumentation session allows all of the groups to share their arguments. One or two members of each group will stay at the lab station to share that group's

FIGURE L23.6

Argument presentation on a whiteboard

The Guiding Question:	
Our Claim:	
Our Evidence:	Our Justification of the Evidence:

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argument, while the other members of the group go to the other lab stations to listen to and critique the other arguments. This is similar to what scientists do when they propose, support, evaluate, and refine new ideas during a poster session at a conference. If you are presenting your group's argument, your goal is to share your ideas and answer questions. You should also keep a record of the critiques and suggestions made by your classmates so you can use this feedback to make your initial argument stronger. You can keep track of specific critiques and suggestions for improvement that your classmates mention in the space below.

Critiques of our initial argument and suggestions for improvement:

If you are critiquing your classmates' arguments, your goal is to look for mistakes in their arguments and offer suggestions for improvement so these mistakes can be fixed. You should look for ways to make your initial argument stronger by looking for things that the other groups did well. You can keep track of interesting ideas that you see and hear during the argumentation in the space below. You can also use this space to keep track of any questions that you will need to discuss with your team.

Interesting ideas from other groups or questions to take back to my group:

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the best argument possible.

Report

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections. Each section should provide an answer for the following questions:

1. What question were you trying to answer and why?
2. What did you do to answer your question and why?
3. What is your argument?

Your report should answer these questions in two pages or less. You should write your report using a word processing application (such as Word, Pages, or Google Docs), if possible, to make it easier for you to edit and revise it later. You should embed any diagrams, figures, or tables into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid.

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