WaterSim Arizona

Modeling Arizona's Regional Water Systems

Author: Decision Center for a Desert City

Contact: Emily Grunspan, Education and Outreach Coordinator at Emily.Grunspan@asu.edu.

Grades: 7-14

Time: Varies by activity

Objectives

Students will be able to:

- gain an understanding of water management for their region in Arizona
- compare different trade-offs associated with choosing different water policies
- compare various stakeholder perspectives as they relate to water
- explain how decisions made among diverse stakeholders involve collaboration and compromise
- generate data and refer to evidence for decision-making processes
- propose a viable solution for sustainable water use in their region

Essential Questions

- What are stakeholders and why are they concerned with water policies?
- What are stakeholders' perspectives on water and how do they compare to one another?
- What are some of the trade-offs associated with different water policies?
- Is there a perfect solution to water management?

Materials

- Stakeholder cards, one per student, distributed evenly
- Student Worksheet: Stakeholders and Systems (Part 1)
- Student Worksheet: Collaborative Water Management (Part 2)
- Student Worksheet: Long-term Drought (Part 3)
- WaterSim Arizona model: https://sustainability.asu.edu/dcdc/watersim/
- Water 101 background presentation
- WaterSim Arizona companion presentation (PowerPoint Presentation)

Advanced Preparation

The instructor will need to become familiar with the basic functions of the WaterSim Arizona model, including understanding the policy choices and sustainability indicators, as well as how to change the drought settings and create a report.

Use the Water 101 presentation and background information to introduce students to water management systems in your region of Arizona.

Included in this curriculum is a vocabulary activity. Students will need to be familiar with key terms in order to complete the activities.

Six stakeholder roles are provided to represent the varied perspectives in different regions of Arizona. The instructor will choose 3-5 stakeholder roles to include in the discussion (See the stakeholder descriptions in this packet and the stakeholder cards).

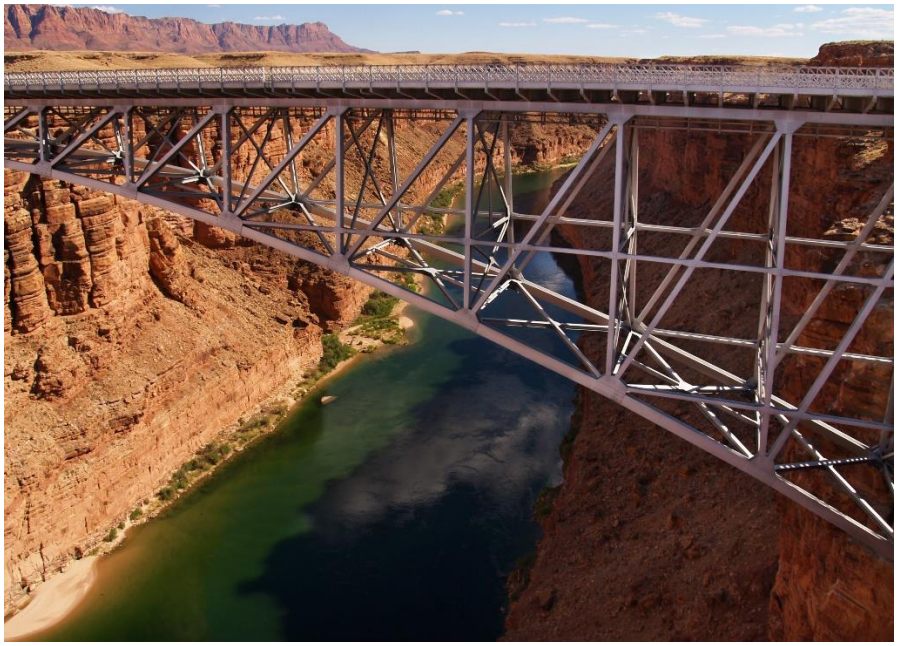
Modifications

To provide open exploration for your students, you may give them access to the WaterSim Arizona model and allow them to explore the features and choices independently before beginning structured activities.

Extensions

WaterStories: Students can compile their summaries at the end of each WaterSim activity to create their own water story about their results and takeaways from the activities.

Instructors may use the student summaries at the end of each activity as student assessments.



Education Standards

Next Generation Science Standards

Disciplinary Core Ideas

- Earth and Human Activity: ESS3.A, ESS3.C, ESS3.D
- Engineering Design: ETS1.A, ETS1.B, ETS1.C

Crosscutting Concepts

- Patterns
- Cause and Effect
- Systems and System Models
- Energy and Matter
- Stability and Function

Science and Engineering Practices

- Developing and Using Models
- Analyzing and Interpreting Data
- Using Mathematics and Computational Thinking
- Constructing Explanations and Designing Solutions
- Engaging in Argument from Evidence
- Obtaining, Evaluating, and Communicating Information

Arizona Science Standards

S1-C2-GR7-PO5
S1-C2-GR8-PO5
S1-C2-GRHS-PO5
S1-C3-GR7-PO5
S1-C4-GR7-PO5
S1-C4-GR8-PO1, PO3, PO5
S1-C4-GRHS-PO3, PO4
S3-C2-GR7-PO1, PO2
S3-C2-GR8-PO1, PO2
S3-C2-GRHS-PO3, PO4, PO5

Arizona Social Studies Standards

S3-C4-GR7-8-PO3
S3-C4-GRHS-PO4
S4-C1-GR7-8-PO3, PO4
S4-C1-GRHS-PO2, PO3
S4-C3-GR7-8-HS (see science standards)
S4-C4-GR7-PO4, PO5, PO8, PO10
S4-C4-GRHS-PO7
S4-C5-GR7-PO1-7
S4-C5-GRHS-PO3, PO6
S4-C6-GR7-PO1-3
S5-C3-GR7-PO4

Arizona Educational Technology Standards

S1-C2-GR7-8-PO1-2
S1-C2-GRHS-PO1
S1-C3-GR7-8-PO1-2
S1-C2-GRHS-PO1

Vocabulary Terms

conservationist	a person who advocates or acts for the protection and preservation of the environment and wildlife.
drought	a prolonged period of abnormally low rainfall; a shortage of water resulting from this.
economy	the measurement of how many goods and services are available and being used in a community.
ecosystem	a biological community of interacting organisms and their physical environment.
effluent	treated wastewater that is not potable.
groundwater	water that is found underground, often connected to rivers and streams above ground.
industry	the production of goods or services. This could include any business activity involving manufacturing or factories.
livelihood	a means of securing the necessities of life.
population growth	an increase in the number of people that reside in a country, state, county, or city.
potable water	water that one can drink safely and that is treated to drinking standards.
reclaimed water	former wastewater that is treated to remove impurities, and used in sustainable landscaping irrigation, to recharge groundwater aquifers, to meet commercial and industrial water needs.
scenario	a hypothesized sequence of possible events.
stakeholder	a person or group with an interest or concern in an enterprise.
surface water	all water above ground including lakes, and rivers, and reservoirs.
sustainability	meeting the needs of the present without compromising the ability of future generations to meet their own needs.
sustainability indicators	the social, economic, and environmental factors that inform water policy.
system	human and environment elements that interact with and influence each other.
trade-offs	the actions of exchanging one thing for another or balancing two or more interests, especially to achieve a compromise.
urbanization	the process by which towns and cities are formed and become larger as more and more people begin living and working in central areas.
water policy	the set of principles that influence how water is allocated and used.
water rights	the legal right to make use of the water from a stream, lake, or irrigation canal.

Additional terms and definitions can be found in the glossary

Recommended Procedure

After students have essential background knowledge, including an introduction to water resources and vocabulary terms, present students with the following problem.

It is 2050 in your region in Arizona. Water supply (availability) and demand (use) need to be managed to provide enough water to maintain a sustainable region. This includes water for:

- agricultural production
- river habitats
- human health and comfort
- economic opportunity (commercial and industrial production and population growth)

Climatic conditions have remained fairly consistent, but population growth has continued and in 2050, water demand exceeds supply.

The Challenge

What if you were in charge? How would you manage your region's water? You have a chance to find out. WaterSim Arizona will act like a time machine to take you back to the year 2015 where you can make your own policy choices to manage water through the year 2050.

Part 1: Stakeholders and Systems Jigsaw

1. Arrange students in groups of four with access to a computer. Assign a stakeholder group to each student group and give each student the appropriate card. (Step 1 on worksheet)
2. Hand out worksheets to each group.
3. Explain to students that each of the groups will represent the interests of stakeholders in one system relevant to water management (see stakeholder summaries).
4. Ask students to review the background information on their stakeholder card for their stakeholder group and answer questions 1-8 on their worksheet.
5. Using this information, have students work together within their stakeholder groups to make a list of goals for water management.

Exploration

6. Allow students to access the WaterSim Arizona model and review the types of Policy Choices available for water decisions. Listed are policy choices that affect water sources (supply) and water consumers (demand). Click on the information button to learn more about each policy choice. (Step 2 on worksheet)

7. Have them list the Policy Choice types in order of priority (highest to lowest) for their group and discuss how they wish to set their Policy Choice buttons in the model to maximize water usage for their stakeholder group interests. Students may select "same," "more," or "less," or they can enter their own value in the corresponding box.

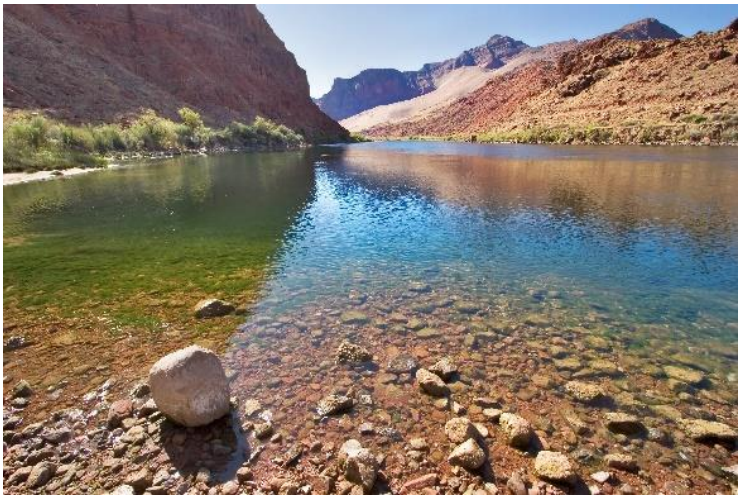
8. Explore the Policy Choices by setting different policy options in WaterSim Arizona. Run the model. Look at the sustainability indicators after running each scenario. What happens to each one?

9. Students continue manipulating the Policy Choices until they find the best combination for their stakeholder group. After coming to a consensus, they will record the results of their sustainability indicators, as well as the Sankey diagram and bar and line charts.

10. When groups come to a consensus they save this scenario as their “individual stakeholder scenario”. Instruct them click on the “settings” button on the lower left side of the window and click “create report”. To save as a pdf, click “print report” and change the print destination to “Save as PDF”. If you are having trouble, check the help file on WaterSim Arizona. They should include their stakeholder name in the file name.

11. Ask students to discuss the following questions:
    - Did you consider the other stakeholder groups when you were making your choices?
    - How did your choices affect the other stakeholder groups (as evaluated using the sustainability indicators)?
    - How were the Sankey diagram and bar and line charts changed from the base scenario?
    - Did the sources of water change for your consumers? How did they change?

12. Each stakeholder group will prepare a short summary about their policy and their results, using these guiding questions:
    - What policy choices did you decide on and why did you choose them?
    - What were your outcomes? Were they positive or negative for your group?
    - How did your choices affect other stakeholder groups?
    - Refer to Sankey diagram and bar and line charts to illustrate the most important outcomes. Individuals will share their summary with their mixed stakeholder groups in the next phase.



Explanation and Elaboration

Part 2: Collaborative Water Management Jigsaw

1. Explain to students they will now adjust to more realistic policy choices by incorporating all stakeholders in the process. Their goal is to find the most sustainable water management plan for the region.
2. Students will now form new groups so that there is at least one person representing each stakeholder role. (Step 1 on worksheet)
3. Explain that each student's job is to represent their stakeholder group, but also to seek compromise with others to come to a consensus about water use policy for their region.
4. Hand out the student worksheets.
5. Allow each member to present their previous policy and results to their group members. Groups will discuss the positive and negative aspects of each policy from each stakeholder's perspective and make a list of the types of trade-offs you can identify among different policies. If necessary, review the term "trade-off" with students.
    - One example of a possible trade-off is that using more surface water will make the environmental indicator less sustainable, because more surface water is going to other uses instead of river habitats.
6. After discussing trade-offs, have groups make a list of goals for water management.
7. Now guide groups to agree on a comprehensive water management plan that illustrates trade-offs among stakeholder's interests. They will make a new list ranking the importance of their Policy Choices.
8. Direct groups to run their simulation by setting the Policy Choices and generating a report to view the output after they come to a consensus once again. Compare to the "base scenario." Students should look at how their sustainability indicators, Sankey diagram and bar/line charts changed. (Step 2 on worksheet)
9. Groups will discuss answers to the following questions:
    - How did your choices affect the sustainability indicators?
    - How are the Sankey diagram and bar and line charts different from the initial setting?
10. Circulate among groups and ask: are you satisfied with these results from your stakeholder's perspective? Encourage them to discuss possible changes and run the simulation again with new choices if necessary.
11. Have each group prepare a 2-3 minute presentation about their results, referring to charts and data to illustrate their points. Address the following questions:
    - What policies did you decide on as a combined group and why?
    - Were the outcomes positive or negative for your stakeholder role? Why?
    - What trade-offs did you identify and how did you take them into consideration?

12. Have each group share their experience. Ask students to notice differences among the groups' strategies. How did they deal differently with trade-offs? Did different groups achieve different compromises? Lead a brief discussion.

Part 3: Long-term Drought

We also can use WaterSim Arizona to project into the future and simulate possible scenarios under different conditions. One possibility is that the region enters a long-term drought with a slow reduction in precipitation, and thus river flow. We will run the model under these conditions:

Challenge: The state of Arizona has experienced drought conditions since 2000. The severity of the drought has reached a point in 2020 where significant impacts on surface water availability has occurred. This drought continued for another 30 years, lasting until 2050.

Working in the same teams, present students with this new problem to solve.

- Click on the Inputs tab. Students can choose the severity of drought to inflict, or you can choose which setting to use (slight, moderate, severe).
- Run the model.
- Note any changes in water supply and demand.

1. Now that they have seen how drought affected their baseline, instruct them to reassess their goals for water management and change their policy choices to reflect these new goals.
   - Run the simulation with different Policy Choices until they come to a consensus.
   - After coming to a consensus, they will record the values, using the Sankey diagram and bar/line charts and sustainability indicators for analysis.

3. Again, ask students to prepare a summary in which they address how their goals changed and how that affected their policy choices. Address the following questions:

   - Did your results surprise you? If so, why?
   - What were the effects of drought on your water management plan?
   - Is your final management plan sustainable? Why or why not?

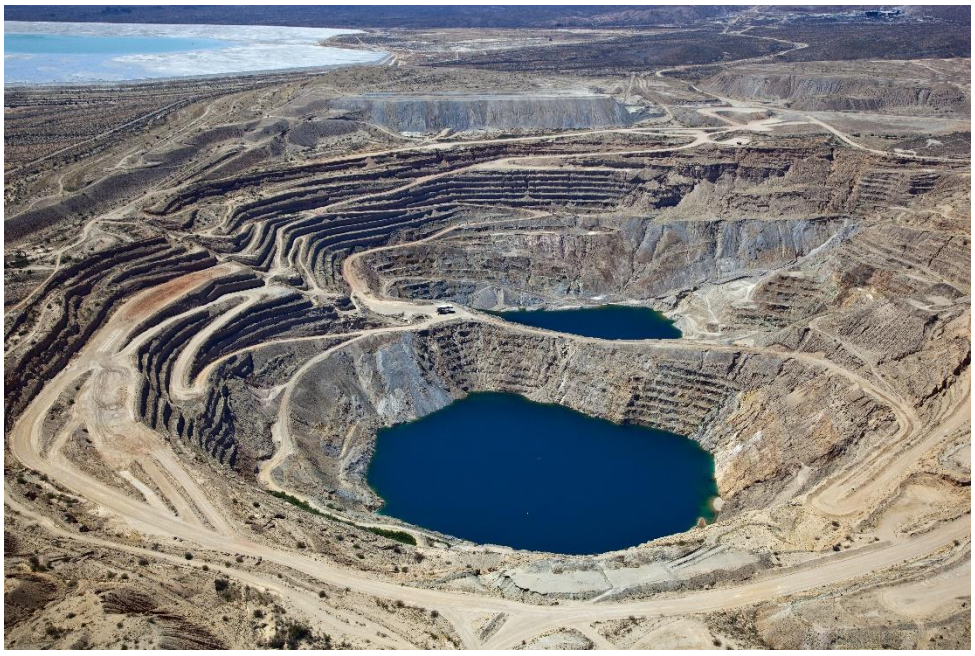
Assessment

There are several opportunities for assessment throughout these activities. Students will participate in the decision-making and computer modeling process and can submit their worksheets and activity summaries to the teacher. They will explain their choices and results from their Stakeholder Groups to their Collaborative Water Management Teams and their results from the second and third steps to the class. Supplementary introductory activities/worksheets can also be developed by the teacher and used for assessment.

Stakeholder Profiles

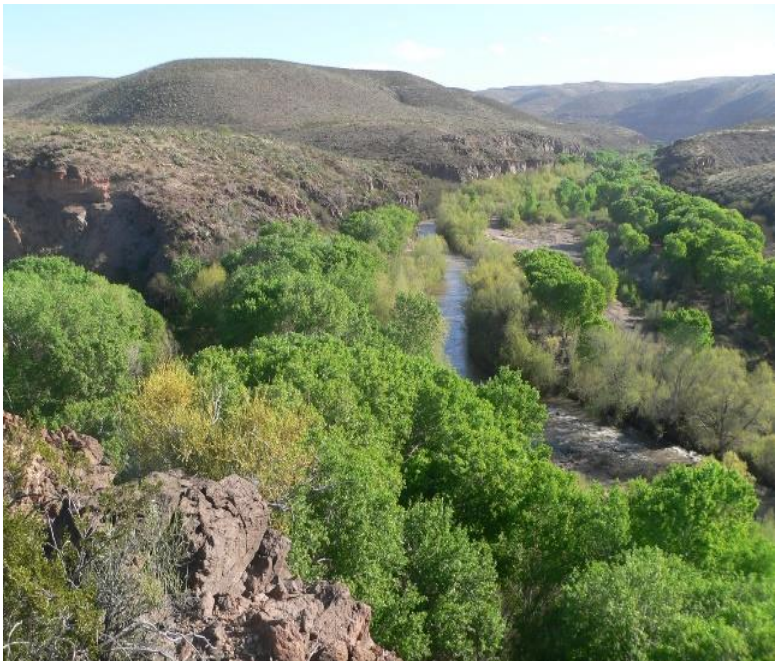
The stakeholder profiles are provided on the following pages.

Business/Industry	
Key Perspectives	• As a business owner, you use water for manufacturing products and delivering services. • Industry can be key for economic development and population growth. • Population growth and strong economic development can bring a skilled workforce and larger market for your products and services. • In addition to water for production, power is needed to keep businesses and industries running. Power production also requires the use of water.
Concerns	• Population growth and economic development can also create competition for water.



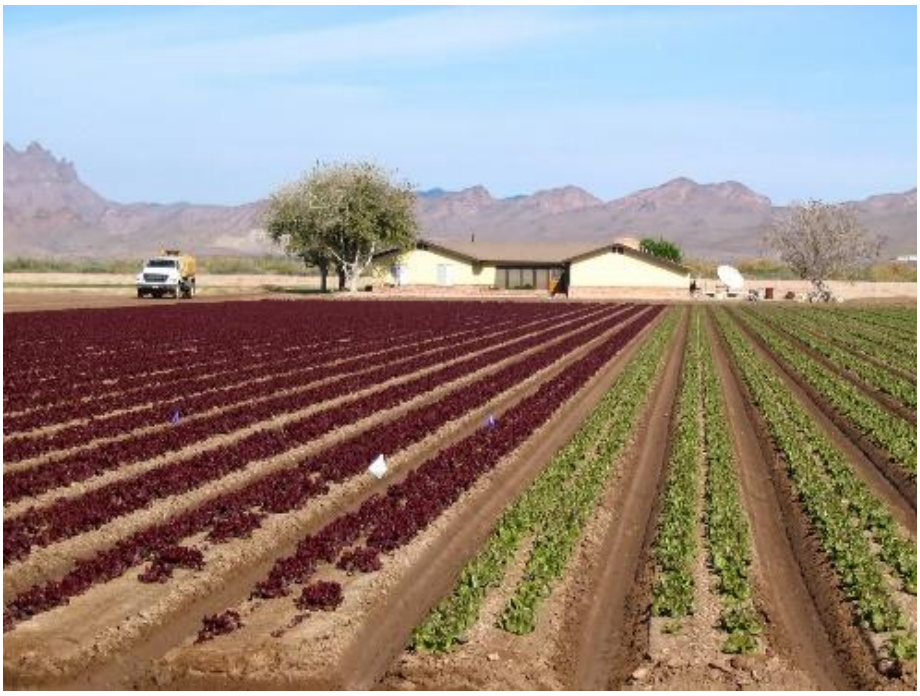
Aerial view of Open Pit Copper Mine near Green Valley, Arizona

Environmentalist/Conservationist	
Key Perspectives	• As an environmentalist, water in rivers and local water bodies is important for the health of ecosystems (plants and animals). • Non-governmental organizations can be involved in projects working to preserve local waters. • Sustainable agriculture includes having agricultural goods produced close to home. • Water conservation strategies can help save water for the future.
Concerns	• Currently, little water is dedicated to maintaining streams, rivers, and associated habitat areas in the state of Arizona. Some water could be used/reserved for these purposes. • Pumping groundwater at a rate higher than it is replenished is not sustainable. In some places, it is unknown how much groundwater there is. Therefore, how long groundwater will last is also unknown.



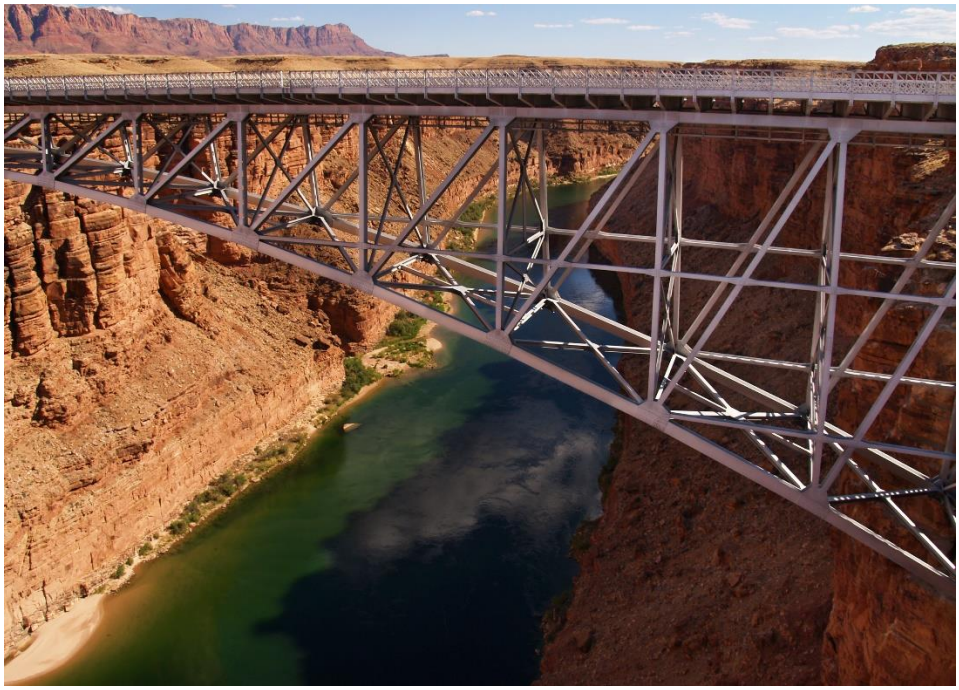
Gila River in Graham County, AZ

Farmer/Agriculture	
Key Perspectives	• This stakeholder encompasses water used by farmers, and the farming industry. • Farmers use water to grow crops to sell and make a living. • A growing regional population increases the demand for agricultural products. • Farming takes place in all counties of Arizona.
Concerns	• Losing land to population growth and urbanization. • Losing water rights. • Factors that put stress on the water supply, such as drought.



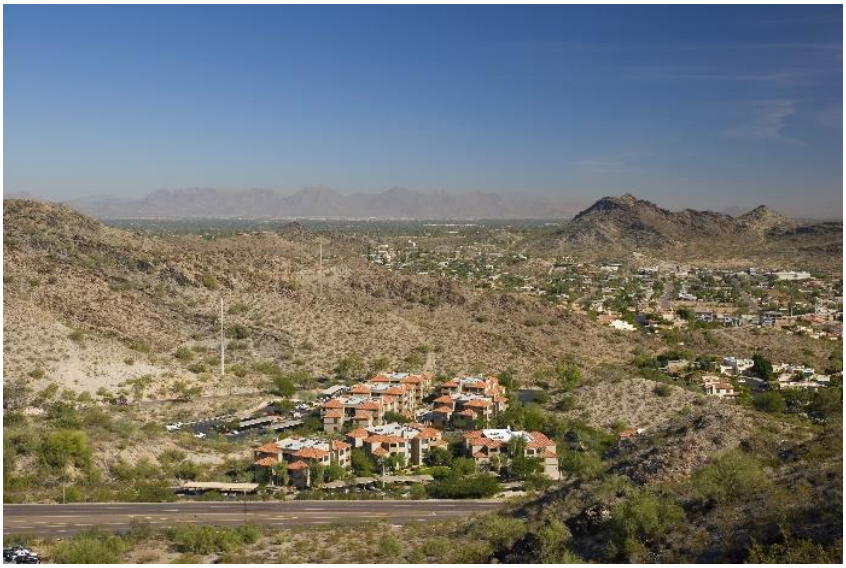
Lettuce fields outside Yuma, AZ

Native American Leaders	
Key Perspectives	• Your job is to ensure that your communities have access to water. • Water needs to be clean, and used to support everyday water needs, as well as agriculture, and cultural uses. • Upstream overuse and contamination can affect your water resources.
Concerns	• While you may have the water rights you need, you may not have the money or infrastructure to get water supplies to the homes and businesses in your communities. • People outside of your community may not understand the ways in which you use water.



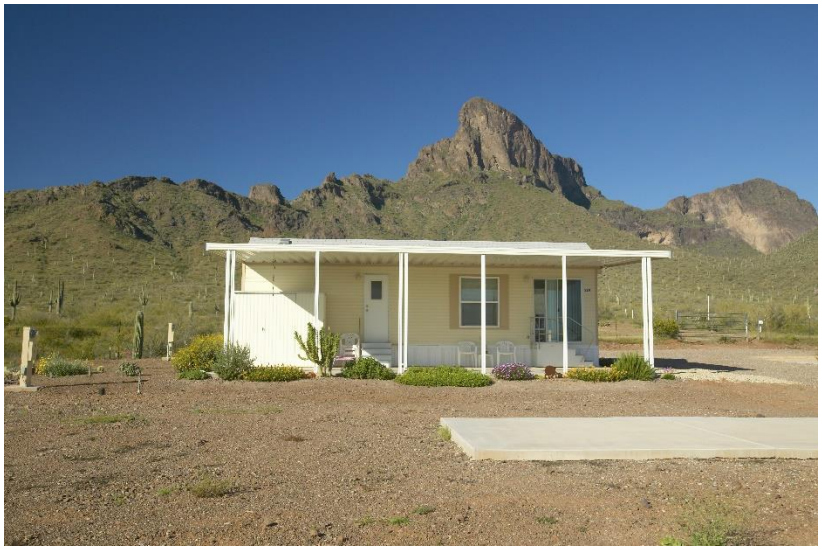
Colorado River at the Navajo Bridge

Water Manager for Cities & Towns	
Key Perspectives	• Manage water for townspeople: ∗ Water used in home, bathing and cleaning, cooking and drinks, irrigating lawns and plants, maintaining swimming pools • Manage water used by businesses to produce products and deliver services. • Water sources (surface water, ground water, etc.) can vary by region. • Economic growth is great for businesses and brings people to the area.
Concerns	• Costs of water – maintaining reasonable water costs keeps the people in cities & towns happy. • Regulations on water use and landscaping, and strategies for saving water may help conserve water, but the people in cities & towns may not want to change their habits. • Factors such as drought and population growth can put stress on water supplies.



Homes outside of Phoenix, AZ

Residents	
Key Perspectives	• You need water for everyday uses, such as bathing and cleaning, cooking and drinks, irrigating lawns and plants, maintaining swimming pools, and other home uses. • You elect officials who manage the water issues in your area. • Resident priorities on how to use water may differ depending on the person and their personal background, ideals, and how they use water on a daily basis.
Concerns	• Population growth and urbanization may increase competition for water. • Decreasing urban water use could require residents at a certain point to change their water use habits, such as removing lawns or reducing car washes, or taking shorter or fewer showers.



A home in Picacho, AZ

WaterSim Arizona
Student Worksheet
Part 1: Stakeholders and Systems

The Problem

It is 2050 in your region. Water supply (availability) and demand (use) need to be managed to provide enough water to maintain a sustainable region. This includes water for:

- agricultural production
  - farming, livestock
- river habitats
  - rivers and surrounding habitats
- human comfort
  - household uses (showering, cleaning dishes, yard irrigation)
- economic opportunity
  - commercial and industrial production
  - population growth (attracting more people to the area for work/living)

Climatic conditions have remained fairly consistent, but population growth has continued and in 2050, balancing water demand and water supply has proven difficult.

The Challenge

What if you were in charge? How would you manage the water? WaterSim Arizona will act like a time machine to take you back to the year 2015 where you will make your own policy choices to manage water through the year 2050.

WaterSim Arizona is a model that will show you how choices made today affect the future water supply and use in Arizona. Let's see how sustainable you can be.

Instructions

- Step 1 -

You will be assigned to a stakeholder group. Each of the groups will represent the interests of stakeholders in one system relevant to water management and attempt to maximize water allocation for:

- Farmer/Agriculture
- Water Managers for People and Business
- Conservationist/Environmentalist
- Business/Industrial Manufacturer
- Native Americans
- Residents

Read your Stakeholder Card and answer the following questions as your assigned stakeholder.

1. What is your role?

2. What role do you play in society? In the economy? In the environment?

3. How can your choices affect people, places, and things in society? In the economy? In the environment?

4. Why do you need water? How do you use water, and what is important to you regarding water resources?

5. What resources, information, or technology might you need to get the most out of your use of water?

6. What do you have in common with other stakeholders? How does your use of water affect other stakeholders, and how do other stakeholders affect you?

7. As a stakeholder, what could you do to help conserve water?

8. Is there any additional information that you know about your role that you would like to include?

9. As a group, make a list of up to five goals for water management, based on your wants and needs. For example, farmers may want enough water to irrigate even in drought periods.

    1. _____

    2. _____

    3. _____

    4. _____

    5. _____

- Step 2 -

1. Review the types of Policy Choices available for water management in WaterSim Arizona. Listed are Policy Choices that affect water sources (supply) and water consumers (demand). Mouse over the terms to learn more about each one. Review the sustainability indicators. Which indicators are most important to you?

2. Go to the WaterSim Arizona website and explore the Policy Choices by setting different policy options. https://sustainability.asu.edu/dcdc/watersim/

    Note: You can change a policy by selecting a button on the scale or by inserting a value in the accompanying box.

    Run the model trying different scenarios until your group comes to a consensus. Record your Policy Choice Settings as well as the Sustainability Indicator outcomes in the charts on the following page.

Write in the available Policy Choices in the corresponding column and record the initial settings (the value selected when you get to the WaterSim Arizona interface). Record the Policy Choices you make for each different scenario, as well as the settings of your consensus. Do the same for the Sustainability Indicators.

Note: Each time you press “run model” you are running a new scenario.

Policy Choices	Initial setting	Scenario 1	Scenario 2	Scenario 3	Consensus

Indicators	Initial setting	Scenario 1	Scenario 2	Scenario 3	Consensus

3. Create an initial report and observe the Sankey diagram and bar/line charts from the “base scenario”. Save report as PDF. Create a report from your model run and save as PDF, including your stakeholder group in the title.

4. Answer the following questions comparing your choices to the “base scenario”:

    - How did your choices affect the other stakeholder groups (as evaluated using the sustainability indicators)?

    - How were the Sankey diagram and line/bar charts changed from the base scenario?

    - Did the sources of water change for your consumers? How did they change?

5. With your group, summarize your results using the questions below to guide you. You will also present this information individually to your Collaborative Water Management Team in the next activity.

    - Which policy choices were most important to you?
    - What policy choices did you decide on and why did you choose them?
    - What were your outcomes? Were they positive or negative for your group?
    - How did your choices affect other stakeholder groups?
    - Refer to Sankey diagram and bar and line charts to illustrate the most important outcomes. Individuals will share their summary with their mixed stakeholder groups in the next phase.

Summary:

WaterSim Arizona
Student Worksheet
Part 2: Collaborative Water Management

Now you will adjust to more realistic policy choices by incorporating all stakeholders in the process. Your goals is to find the most sustainable management plan for the region.

-Step 1-

1. You will now form new groups so that there is at least one person representing each stakeholder. Your job is to represent your stakeholders and also to compromise with others to come to a consensus about water use policy.

Name	Stakeholder
1.	1.
2.	2.
3.	3.
4.	4.

2. Allow each member to present their previous policy and results. Discuss the positive and negative effects of each policy from each stakeholder's perspective. Make a list of the trade-offs that you can identify among different policies. Remember, a trade-off is the action of exchanging one thing for another or balancing two or more interests, especially to achieve a compromise (and a solution).

   1. _____

   2. _____

   3. _____

   4. _____

3. As a group, make a list of up to 5 goals for water management.

    1. _____

    2. _____

    3. _____

    4. _____

    5. _____

4. Now agree on a comprehensive water management plan that illustrates trade-offs among stakeholders' interests. Make a new list ranking the importance of your Policy Choices, from most important to least important.

    1. _____

    2. _____

    3. _____

    4. _____

    5. _____

    6. _____

-Step 2-

1. Explore the Policy Choices by setting different policy options in WaterSim Arizona. You can change a policy by selecting a button on the scale or by inserting a value in the accompanying box. Run the model. Look at the sustainability indicators after running each scenario.

Policy Choices	Initial setting	Scenario 1	Scenario 2	Scenario 3	Consensus

Indicators	Initial setting	Scenario 1	Scenario 2	Scenario 3	Consensus

2. Create a report and observe the Sankey diagram and bar and line charts. Save the report as a PDF.

3. Answer the following questions comparing with the baseline scenario:
   - How did your choices affect the sustainability indicators?

- How were the Sankey diagram and line/bar charts changed from the initial setting?

4. Write a summary about your results, referring to charts and data to illustrate your points. Allow each person to contribute and speak. Use these questions to guide your presentation:

    - How did you combine your goals as a group? What were your priorities?
    - Were the outcomes positive or negative for your stakeholder? Why?
    - What trade-offs did you identify and how did you take them into consideration?

Summary:

WaterSim Arizona
Student Worksheet
Part 3: Long-term Drought

The first scenario did not account for drought. However, the state of Arizona has experienced drought conditions since the year 2000. The severity of the drought has reached a point in 2020 where significant impacts on surface water availability occurred. This drought continued for another 30 years, lasting until 2050.

We also can use WaterSim Arizona to project into the future and simulate possible scenarios under drought conditions.

- Step 1 -

1. On the Inputs tab, select a drought scenario (slight, moderate, severe), keeping the Policy Choices from the previous section. Run the model and observe the results. How did drought affect your scenario?

2. Re-consider your goals and Policy Choices under these new conditions. How will you change your policy choices to manage the drought?

-Step 2-

5. Manipulate the policy choices to find the best combination for your group and also manage drought. Record your values as you run each scenario and record below.

Policy Choices	Initial setting	Scenario 1	Scenario 2	Scenario 3	Consensus

Indicators	Initial setting	Scenario 1	Scenario 2	Scenario 3	Consensus

6. Create a report and observe the Sankey diagram and bar and line charts. Save the report as a PDF.

7. On a separate page, write a summary of your group's Long-term Drought Water Management Plan. In your summary, address these questions:

    - What were the effects of drought on your combined stakeholder water management plan?
    - How did you change your policies to manage the effects of drought?
    - What was the final status of your sustainability indicators?
    - Do you think your final water management plan was sustainable? Why or why not?