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# **Drought Beyond Borders**

**Bilingual Lesson Plans for the Binational Santa Cruz Watershed**

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February 2006

Acknowledgements:

The authors would like to thank the National Oceanic and Atmospheric Administration (NOAA) for its financial support of this project

**Project funded by:**

HELP Initiative Studies in Upper San Pedro River Basin (in U.S. and Mexico) and Washita River Catchment (Oklahoma). National Oceanic and Atmospheric Administration (NOAA) Human Dimensions Program and NOAA/NASA/GAPP Initiative. Robert G. Varady, Principal Investigator, Udall Center for Public Policy Studies, University of Arizona.

Climate Assessment of the Southwest (CLIMAS) Project, “Variability, Social Vulnerability, and Public Policy in the Southwestern United States,” National Oceanic and Atmospheric Administration (NOAA), Jonathan T. Overpeck, Principal Investigator, Institute for the Study of Planet Earth, University of Arizona.

**A special thanks to:**

Dr. Barbara Morehouse, IPSE

Dr. Gregg Garfin, CLIMAS

Dr. Andrew Comrie, CLIMAS

Cynthia Shoemaker, SCRIBE

Kerry Swartz, Project Wet

Diane Austin, BARA

**Subject Area**

Science, Social Studies, Language Arts, Math.

**Grade Level**

Adaptable for 4<sup>th</sup>-8<sup>th</sup> Grade. Fits with Arizona standards for Grade 6 Science and Social Studies.

**Summary**

The students will learn about drought through interactive activities that emphasize questions, discussions, group work, and problem solving. The lesson plan contains five activities, each of which could take one to two hours. The activities build on each other and are best done in consecutive order; however, all activities can be done exclusively. The lessons are geared towards students that live in Southern Arizona and northern Sonora, with case studies specific to the Santa Cruz Watershed. The lessons are also meant to increase the awareness of the regional nature of these issues, and therefore they include activities about the U.S.-Mexico border area.

**Goal**

To explore the concept of drought and climate variability and examine the social and environmental consequences of drought.

**Objectives**

Students will be able to:

- Demonstrate an understanding of drought terminology
- Define drought from various perspectives and devise a general definition of drought
- Graph annual rainfall totals for southeastern Arizona to learn about variation from average rainfall
- Explain the concept of watersheds and describe the different ways people depend on water and are vulnerable to drought
- Understand the complexity of drought across borders and devise solutions to water shortages in a binational watershed
- Write a conservation plan with practical steps to deal with drought in their hometown

**Important Vocabulary**

(All these terms are defined within the text of the curriculum)

- Drought
- Climatic Variability
- Watershed
- Vulnerability

**Homework**

Suggested homework assignments are at the beginning of every activity. If you are doing the lesson plan over one or two weeks, you can have the students compile all their class work and homework in a **Drought Diary**. At the end of the lesson, have the students turn in their Drought Diary for grading.

*Drought Diary Evaluation Matrix*

<i>Assignment</i>	<b>Description for Evaluation</b>	<b>Maximum Points</b>
<b>Activity 1, homework</b>	Summary of 3 drought interviews. Each summary should respond to the following questions: 1) How would you describe drought? 2) Have you ever experienced drought? 3) How has drought affected you personally? If you haven't been affected, why not?	30
<b>Activity 2, in class</b>	Questions 1-5. Answers provided in box on pg. 8.	10
<b>Activity 3, homework</b>	One page creative writing exercise from the perspective of a farmer or rancher in the early 1900s. Response to how he/she would adapt to a long drought.	20
<b>Activity 3, in class</b>	Answer questions 1-6. Answers provided in box on pg. 11.	10
<b>Activity 4, homework</b>	Students must find newspaper article about water issues along the U.S.-Mexico border. The entry should summarize the article and include two questions they have about the article.	20
<b>Activity 4, in class</b>	Answer questions 1-4. Answers will be subjective, so now answers are provided. Make sure students substantiate their answers.	20
<b>Activity 5, homework</b>	One page response to the following questions: Should the residents of Nogales, Sonora be concerned about preserving the riparian area in Arizona? Why? Should residents in Nogales, Arizona conserve water when Nogales, Sonora is having a water shortage? Why? Estimate of how much water their family uses in one week. Entry includes a list of all the ways the student uses water at home and estimates of how much water they use per week for each activity.	20
<b>Activity 5, in class</b>	Individual entry on five ways they would reduce the amount of water they use in their home. Also, group conservation proposal with 5 conservation measures with the following information for each measure: who would participate, what behavior/action is expected, and how would this save water.	20
<b>Participation</b>	Participation in group activities and class discussion	10
<b>Total Points</b>		<b>160</b>

**Arizona Standards**

**Science, Grade 6**

**Strand 3:** Science in Personal and Social Perspectives

**Concept 1:** Changes in Environments

PO2: Describe how people plan for, and respond to, the following natural disasters: drought, flooding and tornadoes

**Social Studies, Grades 6-8**

**Standard 3: Geography**

**3SS-E5:** Describe natural and human characteristics of places and use this knowledge to define regions, their relationships with other regions, and their patterns of change, with emphasis on:

PO1: common characteristics of regions at local, national, and international scales on the basis of climate, landforms, ecosystems, and culture

**3SS-E7:** Explain the effects of interactions between human and natural systems, including the changes in the meaning, use, and distribution of natural resources, with emphasis on:

PO1: the physical processes that influence the formation and location of resources, including water inequities in Arizona

PO2: consequences to humans of earthquakes, hurricanes, tornadoes, flash floods, and other natural hazards

PO3: how and why humans modify ecosystems, including deforestation and desertification

PO4: how changes in the natural environment can increase or diminish its capacity to support human activities

PO5: how technological modification in one place often leads to changes in other locations, including how the control of rivers impacts the development of Arizona

PO6: ways that humans depend upon limited resources and adapt to, and affect, the natural environment

### Additional Sources of Information

For Teachers	
CLIMAS (Look at publications page for <i>Drought and Climate in Arizona: Top Ten Questions &amp; Answers</i> )	<a href="http://www.ispe.arizona.edu/climas/">http://www.ispe.arizona.edu/climas/</a>
U.S. Drought Monitor	<a href="http://www.drought.unl.edu/dm/monitor.html">http://www.drought.unl.edu/dm/monitor.html</a>
NOAA Drought Information Center	<a href="http://www.drought.noaa.gov/">http://www.drought.noaa.gov/</a>
National Weather Service – Tucson	<a href="http://www.wrh.noaa.gov/tucson/">http://www.wrh.noaa.gov/tucson/</a>
Udall Center – Environmental Research on the U.S.-Mexico Border Area	<a href="http://udallcenter.arizona.edu/">http://udallcenter.arizona.edu/</a>
What is Drought?	<a href="http://www.drought.unl.edu/whatis/concept.htm">http://www.drought.unl.edu/whatis/concept.htm</a>
For Students	
U.S. Drought Monitor	<a href="http://drought.unl.edu/dm/">http://drought.unl.edu/dm/</a>
SAHRA	<a href="http://www.sahra.arizona.edu/newswatch/index.html">www.sahra.arizona.edu/newswatch/index.html</a>
What is Drought?	<a href="http://www.drought.unl.edu/kids/index.htm">http://www.drought.unl.edu/kids/index.htm</a>
Related Curriculum	
Project WET	<a href="http://ag.arizona.edu/AZWATER/wet/">http://ag.arizona.edu/AZWATER/wet/</a>
The Santa Cruz River, Its People and Environment (SCRIFE)	<a href="http://www.sccedu.org/scripe/">http://www.sccedu.org/scripe/</a>
GeoMath and Geoliteracy - Created by the Arizona Geographic Alliance	<a href="http://alliance.la.asu.edu/azga/">http://alliance.la.asu.edu/azga/</a>

## Activity 1: Understanding Drought

Estimated Time	One hour
Homework	Have the students ask 3 people (family, neighbors, teachers) about drought in the style of an informal interview. Have the interviewees answer the following questions: 1) How would you describe drought? 2) Have you ever experienced drought? 3) How has drought affected you personally? If you haven't been affected, why not? Have the student write up a summary of what their interviewees said. Allow the students up to one week/weekend to complete this task.
Objective	Define drought from various perspectives and devise a general definition of drought

### Step 1

The purpose of this exercise is to get students to think critically about the concept of drought and all of its implications. Have the students brainstorm what they think would cause a shortage of water (less rain, hotter weather, more development, leaks in infrastructure, more water used on agricultural crops, etc.). Write their ideas on the board. Then have the students brainstorm who would be affected by a shortage of water over an extended period of time. List all their ideas on the board. You can assist the students to think of all the following groups: farmers, ranchers, industry, mining, wildlife, ecosystems, developers, and city planners.

### Step 2

Now divide the students into 6 groups to represent each of the following local people. Have each group write a definition and description of drought from the perspective of the person they represent. Each group should figure out how a shortage of water would affect or concern the person they represent.

- Farmer
- City Mayor
- Wildlife Biologist
- Urban homeowner
- Weather man (meteorologist)
- Tourist

### Step 3

Have each group share their definitions of droughts with the class. Have the groups write their definition on the board, so the students can see all the diverse perspectives on drought. After sharing, have the students come up with a general definition of drought that all the groups could agree on.

In general, the definition of **drought** is a shortage of water over a period of time. The period of time in which a drought occurs may be extended or short, but in both cases the water shortage will have an impact on humans and/or wildlife. For a good summary of drought and its varying definitions, go to the National Drought Mitigation Center's website, located at: <http://www.drought.unl.edu/whatis/what.htm>.

#### Step 4

Finish the discussion by asking the students if their hometown/local area is currently in a drought or has been in a drought recently. Ask them to guess how often a drought occurs in their local area.

#### Step 5

Now practice interviewing to prepare the students for their homework. Have one of the students interview the teacher and/or have the students interview each other. You may want to use different questions than those provided for the student.

### Activity 2: Is Drought Normal?

Estimated Time	One hour
Materials Provided	Precipitation Data Worksheet (p. 18)
Materials Needed	calculator, graph paper
Objective	Graph annual rainfall totals for southeastern Arizona to learn about variation from average rainfall

#### Step 1

Ask the students what they think the average yearly rainfall is for the area. Then tell the students the average yearly rainfall for their local area. The long-term precipitation average for Southeastern Arizona, Climate Division 7, is 14.3 inches/year<sup>1</sup>.

#### Step 2

Put the students into pairs to graph the yearly rainfall total for 4 cities in the Santa Cruz Watershed from the last 16 years. The data is found on the Precipitation Data Worksheet at the end of the packet – you can hand out this worksheet or write the data on the board. There is data for Tucson, Green Valley, Tumacacori, and Nogales. Have the students graph all of the cities' precipitation data. After the students have completed the graphs, look at the rainfall graphs on an overhead with the students and compare them to see if they were all above average or below average the same years.

#### Step 3

After the students have plotted the total annual rainfall for 1989 to 2004 in Tucson (and/or the other cities), have them draw a line through the graph indicating the annual rainfall norm. The norm for each city is the given at the bottom of the precipitation data table (the norm was calculated by the National Weather Service).

Once they have finished their graph, explain that all points below the line are less than average and all points above the line are greater than the average. Use the graphs provided (p. 19-20) to illustrate these points. *\*Using 16 years of data is enough to illustrate the concepts of climate variability and drought, however, teachers should explain to the students that a much longer*

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<sup>1</sup> From McPhee, J., Comrie, A., and Garfin, G. 2004. Drought and Climate in Arizona: Top Ten Questions & Answers. Available at: <http://www.ispe.arizona.edu/climas/pubs/topten.html>.

period of data is needed to find a workable average yearly rainfall. An historical average is often found using 30 years of climate data<sup>2</sup>.

#### Step 4

Explain that a drought is determined somewhat arbitrarily depending on the perspective (meteorological, hydrological, agricultural, and socioeconomic). Often times, drought is determined by comparing the current precipitation with a historical average. The drought years would be a percentage less than average rainfall. For example, a severe drought could be considered rainfall totals that are 75% of the historical average.

#### Step 5

Have the students look at the graphed data and answer the following questions in their *drought diary*:

- 1) How often does below average rainfall occur for each city?
- 2) Does below average rainfall occur in consecutive years in each city?
- 3) How often was rainfall above average in each city?
- 4) If above average or below average rainfall occurs on a regular basis, is it a normal event?
- 5) Can we expect drought to happen again in the future? Why?

#### The Different Faces of Drought

(Corresponds with Step 4)

Drought can be experienced in different ways such as: meteorological, hydrological, agricultural, and socioeconomic.

Meteorological drought is usually defined by a percentage of rainfall below average.

Agricultural drought is measuring drought from a farmers' or ranchers' perspective. They would be concerned with things like lack of precipitation, low soil moisture, and reduced ground water. Agricultural drought will be felt right away if farmers depend on rainwater. If farmers depend on surface or groundwater (like many farmers in Arizona), drought will occur when surface or groundwater supplies dwindle – which is known as hydrological drought.

Hydrological droughts will often be defined on a watershed basis by shortages in surface and groundwater supplies. Socioeconomic drought happens when the demand for a product (food, grains, fish, hydroelectric power, forage, etc.) exceeds supply due to a water shortfall from drought.

From the Drought Mitigation Center:

<http://www.drought.unl.edu/whatis/concept.htm>

#### Answers:

- 1) Tucson - 11, Green Valley - 9, Nogales - 10, Tumacacori - 9
- 2) Yes
- 3) Tucson - 5, Green Valley - 7, Nogales - 6, Tumacacori - 7
- 4) Yes
- 5) Yes, drought is expected to happen again in the future because below average rainfall is a normal event.

<sup>2</sup> Understanding and Defining Drought, from the National Drought Mitigation Center (NDMC), available at: <http://www.drought.unl.edu/whatis/concept.htm>.



### Step 6

Show a graph of precipitation for Tucson/Arizona from the last 100-500 years. Explain the concept of climatic variability by showing how often the precipitation changes, and how it is not often at the average. **Climate variability** refers to the normal variations in climate, like when variables such as temperature and precipitation depart from the average.<sup>3</sup> Explain that drought and wet periods are common and frequent events in Arizona's climate – therefore they can be considered normal events.

In addition, explain to the students that there can be wet years in the middle of a long-term drought. This means that a year or several years of above average rainfall can occur in the midst of a long period of below average rainfall.

Reconstructed climate graphs can be found at the CLIMAS website:

<http://www.ispe.arizona.edu/climas/research/paleoclimate/product.html>. Teachers can access climate graphs for each climate division in Arizona.

### Step 7

Have the students discuss the following questions in groups: Do plants and animals experience drought or is drought a human concept? Have them choose yes or no and explain why. Have them write a paragraph in their drought diary with their response to this question.

## Activity 3: Shared Water Resources of the Santa Cruz Watershed

Estimated Time	One to one and a half hours
Homework	Give the students the handout on the Santa Cruz Watershed to read at home. Have them do a creative writing exercise in their drought diary in which they write a one page diary entry from the perspective of a farmer or rancher in the early 1900s. The farmer/rancher is writing about a long drought (10 years) and how he/she adapted to the dry conditions to survive.
Materials Provided	Watershed Diagram (pg. 21), Vulnerability to Drought Handout (pg. 22), and Santa Cruz Watershed Handout (pg. 23-24)
Objective	Understand the concept of watersheds and compare the way different people are vulnerable to drought

### Step 1

Explain the concept of **watersheds**. A watershed is a physical boundary containing an area of land where all the water drains to a common outlet. The area of land shares common surface and ground water. Tell the students that everybody lives in a watershed! Show the students the watershed diagram, and explain how all the rainfall that falls in that area, end up draining into one common area.

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<sup>3</sup> From 'Climate Variability' available at [www.ucar.edu/learn/1\\_2\\_2\\_9t.htm](http://www.ucar.edu/learn/1_2_2_9t.htm).

## Step 2

Now show the students a map (provided) of the Santa Cruz watershed. Point out the boundaries of the watershed, and explain that all the rainfall within this area eventually drains into the Santa Cruz River. Explain that all the people, plants, and animals in the watershed share the same source of water. Point out the cities of Tucson, Nogales, Arizona, Nogales, Sonora, the Santa Cruz River, the border, and other important features like reservations and highways within the watershed.

## Step 3

Use the following questions to discuss the concept of climate in the watershed:

- Where have you visited in the watershed (including the Mexican portion of the watershed)?
- Was the climate in the areas you visited similar to the weather in your hometown?
- If there is a drought in your hometown, do you think there is a drought in the other areas of the watershed?

Explain to the students that all the areas of the watershed share a similar climate, however there are variations in rainfall and temperatures (as seen in Activity 2). Climate variations in a geographically small area can be the result of changes in elevation and the presence of topographic features like mountains. If there is drought in one area of the watershed, it is likely that there will be drought in the entire watershed since the watershed shares common surface and groundwater.

## Step 4

Read to the class the short descriptions about two different families of the Santa Cruz Watershed in the present day.

The stories describe an urban family and a rural family and how they depend on the environment, climate, and natural resources such as water.

### Rural Family

Mr. and Mrs. Smith are farmers that have property along the Santa Cruz River. They have a medium sized farm where they grow pistachio nuts and apples. In addition they have five horses on their property, which roam freely to graze. Because they are farming in a dry climate, Mr. and Mrs. Smith depend on irrigation water from the Santa Cruz River. The crops that the Smith's grow and sell are their main source of income.

### Urban Family

Mr. and Mrs. Garcia live in Tucson with their two children. They live in a house with a yard near the center of town. Mr. Garcia is a teacher and Mrs. Garcia manages a restaurant. In their

### Teaching Watersheds (Corresponds with Step 1)

Direct students to the National Geographic Website: <http://nationalgeographic.com/geographyaction/rivers/>. Have the students look at the interactive river system. You can also print out the river illustration as a handout. This activity is a good way for students to visualize a watershed.

There are also watershed activities provided in the Project Wet curriculum. Arizona Project Wet has teaching aids like small-scale watershed models and a water history trunk. To learn more about their teaching aids, go to: <http://www.ag.arizona.edu/AZWATER/WET/resources/teachingaids.html>.

spare time, Mr. and Mrs. Garcia like to garden. They have a vegetable garden and a variety of non-native plants that need to be watered frequently. They have a lawn in the front yard and a pool in the backyard. Their water is supplied by the city of Tucson.

### Step 5

Have the students compare and contrast the two families and answer the following questions in small groups. Have them write their responses in their *drought diary*. Write the questions on the board for guidance, or give the students the *Vulnerability to Drought Handout*.

- 1) What natural resources does each resident depend on?
- 2) What are the main uses of water for each family?
- 3) Who probably uses more water? Why?
- 4) Which family's job depends on the climate of Arizona? How?
- 5) If there were a long drought, how would each family be affected?
- 6) If there were a long drought, which family would be affected more? Why?

#### Answers:

1. Rural: water (groundwater), soil, sunshine and rain. Urban: water (groundwater), soil, sunshine and rain.
2. Rural: watering agricultural crops, water for their horses, and water use in the home. Urban: watering garden, watering lawn, water for pool, and water use in the home.
3. The rural family probably uses more water because they are watering crops that they sell to the market. The crops they grow require irrigation water.
4. The rural family's job depends on the climate of Arizona. They depend on the warm, sunny weather to grow their crops. Though rain helps, they depend on irrigation water for their crops.
5. Rural: Their crops will be negatively affected. They will need more irrigation water. Their supply of irrigation water may be limited during a drought, since surface and groundwater in the river will be low. During a drought, the pasture will dry up. They will probably need to buy food to feed their horses, instead of letting them feed in the pasture. Urban: The urban family's garden and landscape vegetation will require more water. Otherwise, the urban family will not be affected by the drought. They receive water supply from the city, which will remain the same. The urban family would be affected if the city of Tucson implemented mandatory conservation measures.
6. The rural family would be affected more, because they depend on water supply directly for their jobs. If surface and groundwater in the Santa Cruz river become limited, the water available for irrigation will become limited. If their crops do not produce well because of the drought, they will not make as much money from their crops. It will also be more expensive to feed their horses, if pasture is not growing. So the rural family will be hit hard economically, while the urban family will not be affected economically.

## Step 6

Have the students share their answer to the final question. Then explain the concept of **vulnerability**. Show how the two residents demonstrate different vulnerabilities to climate change. Discuss how the two families are affected differently by drought. The urban residents may experience some inconvenience with their landscaping, however they will be virtually unaffected by a drought (unless the city creates water use restrictions). The rural family, on the other hand, will be severely affected by a drought, since their livelihood depends on their crops. If they do not have enough water for their crops, their crops may fail, and they will not make a living. A drought would also affect the pasture that their horses feed on. They may have to buy hay to feed the horses, if the pasture does not grow.

Additional note to teachers:

There are two scenarios in which urban residents in Tucson can be more affected by drought: 1) a long-term, severe drought in the upper Colorado River basin that affects the CAP (Central Arizona Project) water supply to Tucson, or 2) water shortages brought on by over-pumping groundwater, in which a minor dry spell could become a major drought problem.

## Step 7

Finish up the activity by asking the students what other factors would make a person vulnerable to drought. Ask them what other jobs depend on rainfall. They can use examples from their own experience or from the experiences of their families and friends from anywhere in the Southwest. Discuss factors that would reduce one's vulnerability to drought such as: the government, multiple sources of income, social networks, and surplus income (wealth).

## Vulnerability to Drought Across the U.S.-Mexico Border

(Corresponds with Step 6)

Vulnerability is defined as, “the ability or inability of individuals and social groupings to respond to, in the sense of cope with, recover from or adapt to, any external stress placed on their livelihoods and well-being” (Kelly and Adger 2000).

Vulnerability to drought and climate change can vary across geographic areas with the same climate. The following factors can affect vulnerability: class, ethnicity, government response programs, technology, access to land, and individual decision-making (Vásquez-León et. al. 2003).

Nogales, Sonora and Nogales, Arizona share climatic conditions and water resources, however residents on each side of the border have different vulnerabilities to drought. Residents of Nogales, Sonora have a higher vulnerability to drought due to limited distribution of city water, a large growing population, lack of government relief programs, and lack in financial resources. Residents on Nogales, Arizona are less vulnerable to drought because everyone receives city water, the city has water reserves, and there are more resources from the government to deal with drought.

Kelly PW, Adger WN. 2000. Theory and practice in assessing vulnerability to climate change and facilitating adaptation. *Climatic Change* 47(4), 325-352.

Vásquez-León, M., West, C.T. and Finan, T.J. 2004. A Comparative Assessment of Climate Vulnerability: Agriculture and Ranching on both Sides of the US-Mexico Border. *Global Environmental Change* 13(3), 159-173.

## Extension Activity

Take the students on a field trip to Tumacacori National Historical Park to learn more about the Santa Cruz River Environment.

### **Activity 4: Drought across Borders**

Estimated Time	One to two hours
Homework	Have the students look for newspaper articles on water issues (drought, flooding, conservation, water companies, water planning, riparian areas, etc.) along the U.S.-Mexico border. Suggest that they look for articles about Nogales, Arizona and Nogales, Sonora. Suggest the students look at the SAHRA newswatch website: <a href="http://www.sahra.arizona.edu/newswatch/index.html">www.sahra.arizona.edu/newswatch/index.html</a> . Have the students write an entry in their drought diary summarizing the article and writing two questions they have about the article.
Materials Provided	Drought Across Borders handout (p. 25-26)
Objective	Understand the complexity of drought across borders and devise solutions to water shortages in a binational watershed

#### **Step 1**

Review what was learned from Activity 3 – about the shared water resources of the Santa Cruz Watershed. Emphasize that Nogales, AZ and Nogales, Sonora have a common water source. Show the students the map of the Santa Cruz watershed again.

#### **Step 2**

Read the following climate change scenario to the students or pass out the *Drought Across Borders* handout for the students to read.

#### **Setting:**

The binational Santa Cruz Watershed in Arizona and Sonora.

#### **Climate Scenario:**

Southeastern Arizona and northern Sonora are in the midst of a long-term drought that has already lasted five years. The drought is expected to last five more years. The drought has resulted in reduced rain during the winter. The decrease in rain has led to less surface and ground water in the Santa Cruz Watershed. Nogales, Sonora and Nogales, AZ both depend on the water from the Santa Cruz Watershed to supply water to their local residents, businesses, and industry. The drought has put added stress on the already limited supply of water in the Santa Cruz Watershed.

#### **Drought Dilemma, Part I:**

Nogales, Sonora is experiencing water shortages and is struggling to provide water for all its residents, businesses, and industry. The drought has caused the wells in the Santa Cruz River to

dry up. The city is depending on water from outside the Santa Cruz Watershed and has imposed water restrictions.

Across the border, in Arizona, Nogales and the surrounding communities are still able to meet all their water supply needs. In the Santa Cruz Watershed, Nogales, Arizona has larger aquifers (meaning more groundwater storage) than Nogales, Sonora. Nogales, Arizona also has groundwater recharge from treated wastewater both from Nogales, Arizona and Nogales, Sonora. Therefore, Nogales, Arizona has more surface water and groundwater than Nogales, Sonora. Nogales, Arizona also has a much smaller population than Nogales, Sonora.

### Step 3

Now divide the students into small groups to discuss and answer the following questions. Have students write their responses in their *drought diary* or on the worksheet provided.

- 1) Should Nogales, Arizona share water with their neighboring town across the border? Why or why not?
- 2) Should Nogales, Arizona and Nogales, Sonora manage their water together or separately? Why?
- 3) Could water conservation be used to help solve this problem? If so, how?
- 4) Should water conservation only occur during a drought period, or at all times? Why?

### Step 4

When the groups are done answering the questions, read Part II of the Drought Dilemma.

#### **Drought Dilemma, Part II:**

The Santa Cruz River is a river habitat that supports threatened wildlife and is an important corridor for migrating species such as birds. Although the Santa Cruz River is dry in some areas, there is a constant flow of water downstream of the wastewater treatment facility, which is located in Arizona. This constant flow of water creates an important river habitat that supports a number of plants and wildlife. Because of the drought, there is less water within the Santa Cruz River, and there is more pressure to withdraw water downstream of the wastewater treatment facility. If water is not saved for the river ecosystem, the many bird and fish species will suffer.

### Step 5

Divide the students into groups to role-play as community watershed groups. As a group, the students will devise a campaign to protect the river species. The groups will need to plan one community event to raise awareness about protecting the river species. To plan the community event, determine the following:

- Who do you want to attend?
- How will you get those people to attend?
- What will you do at the community event?
- How will you get community members to help protect the river species?

Each group will write a one page proposal that outlines the community event. When the groups are done, have the groups share their community event with the class.

### Step 6

As a final wrap up, have the students write a one page response to the following questions in their *drought diary*:

Should the residents of Nogales, Sonora be concerned about preserving the riparian area in Arizona? Why?

Should residents in Nogales, Arizona conserve water when Nogales, Sonora is having a water shortage? Why?

## Activity 5: Drought in Your Hometown. What Would You Do?

Estimated Time	One hour
Homework	Have the students figure out how much water their family uses in one week. Have them list all the ways they use water at home, and estimate how much water they use per week on that activity. National Geographic provides a worksheet online to tally household water use: <a href="http://nationalgeographic.com/geographyaction/rivers/ax/PDF1_WaterTally.pdf">http://nationalgeographic.com/geographyaction/rivers/ax/PDF1_WaterTally.pdf</a> . A water tally is also provided in the packet.
Materials Provided	Water Tally (pg. 27)
Objective	Write a conservation plan with practical steps to deal with drought in their hometown

### Step 1

Read the following drought scenario to your students:

It is the fifth year of drought in your hometown. There has been very little rain during the summer monsoon and below average rainfall during the winter. The drought is large-scale and covers the whole state of Arizona and Sonora, Mexico. The mayor asks the residents of your town to voluntarily reduce the amount of water they use every day because the city water supply is very low.

### Step 2

Have each student write in their *drought diary* five ways they would reduce the amount of water they use in their home. The water tally worksheet can aid the students in this task. Students can share some of their ideas with classmates.

### Step 3

Then have the students get into groups and come up with ways that households, neighborhoods, and businesses in your town could work together to reduce water usage. Have them come up with five ways for the community to conserve water. Have the students write up their proposal in their *drought diary*. Their proposal should include 5 conservation measures with the following information for each measure:

- who would participate
- what behavior/action is expected
- how would this save water

#### **Step 4**

When they are done, have each group share their proposals for community water conservation in front of the class.



## **Worksheets, Handouts and Additional Materials for Drought Lessons**

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## Precipitation Data in the Santa Cruz Watershed

### Yearly Rainfall Totals

<b>Year</b>	<b>Tucson (UA)</b>	<b>Green Valley</b>	<b>Nogales</b>	<b>Tumacacori</b>
2004	8.69	11.78	10.91	10.75
2003	10.44	13.12	16.61	12.17
2002	7.47	10.96	8.06	9.85
2001	8.56	16.23	14.53	16.62
2000	11.53	18.48	25.85	19.23
1999	7.52	13.69	13.02	9.92
1998	16.06	14.54	17.98	16.07
1997	9.15	10.26	14.84	19.12
1996	11.13	10.07	10.79	10.83
1995	9.68	9.59	14.36	15.26
1994	14.55	15.47	20.05	26.51
1993	15.19	22.00	28.22	23.42
1992	14.76	18.33	20.46	23.51
1991	10.64	15.76	19.72	17.66
1990	14.80	21.68	21.53	20.78
1989	6.93	10.10	13.99	10.46
<b>Norm</b>	<b>12.00</b>	<b>15.45</b>	<b>19.03</b>	<b>17.40</b>

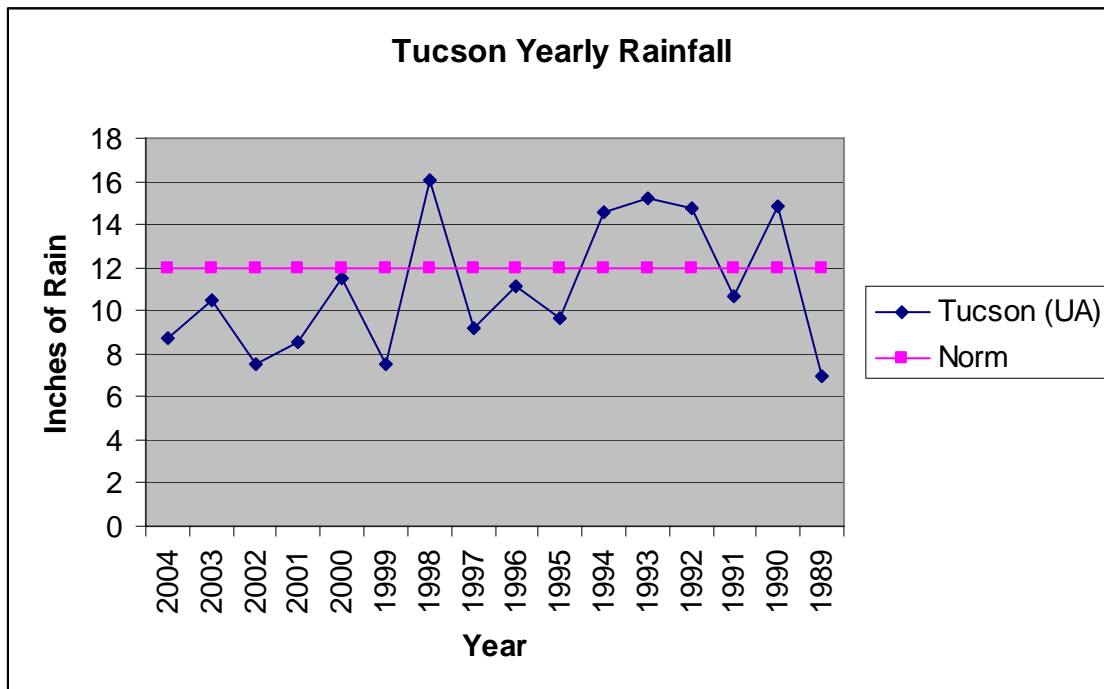
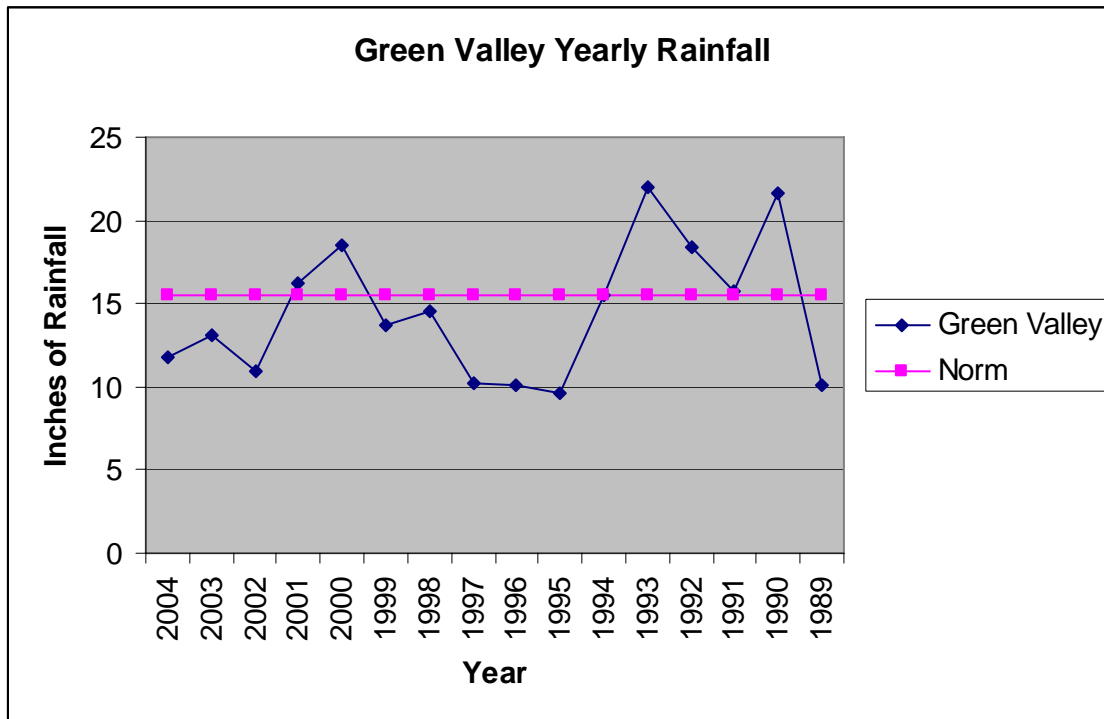
\* Data is from the National Weather Service Forecast Office, found at:  
[http://newweb.wrh.noaa.gov/twc/climate/seaz\\_yearly\\_rainfall.php](http://newweb.wrh.noaa.gov/twc/climate/seaz_yearly_rainfall.php)

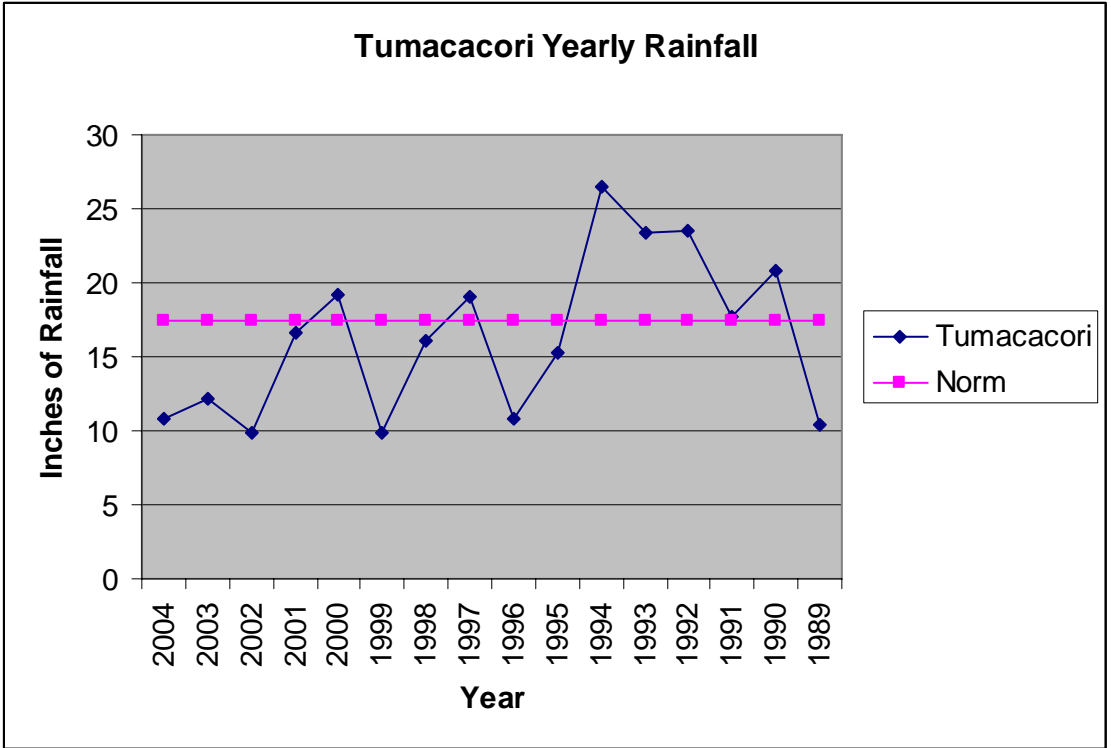
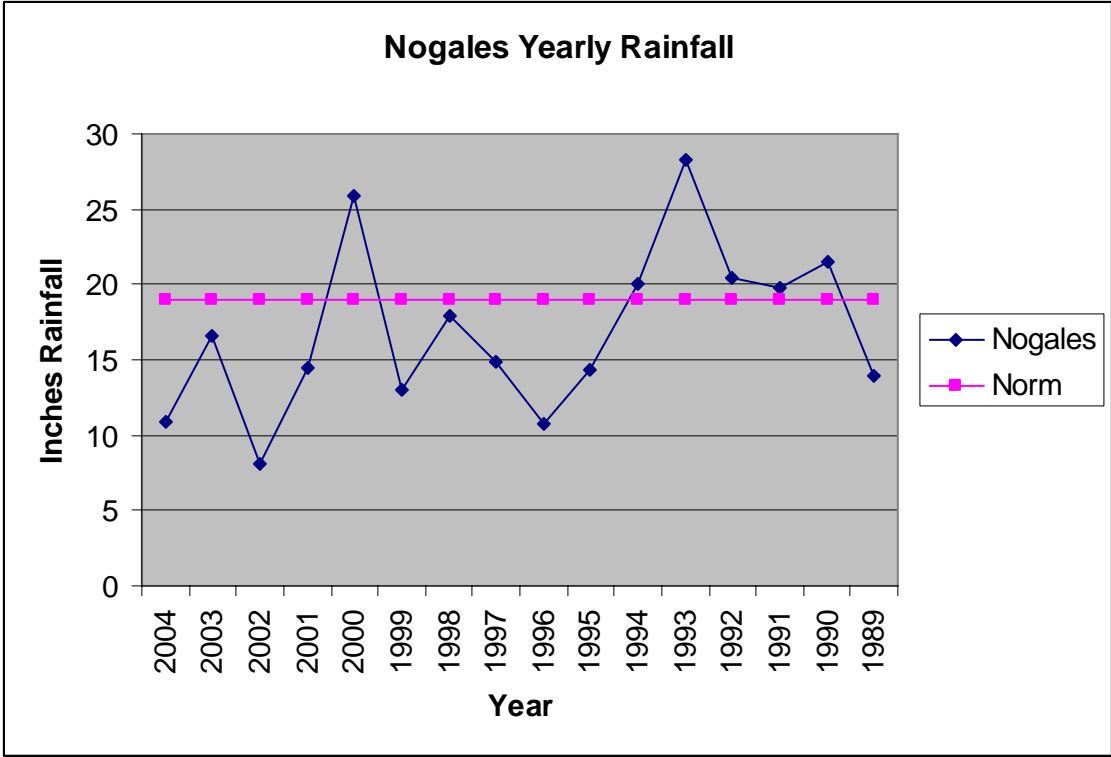
Graph the yearly rainfall total for Tucson, Green Valley, Nogales, and Tumacacori from the last 16 years. Make separate graphs for each city. After you have plotted all the points for each city, draw in the yearly rainfall norm (as given at the bottom of the chart).

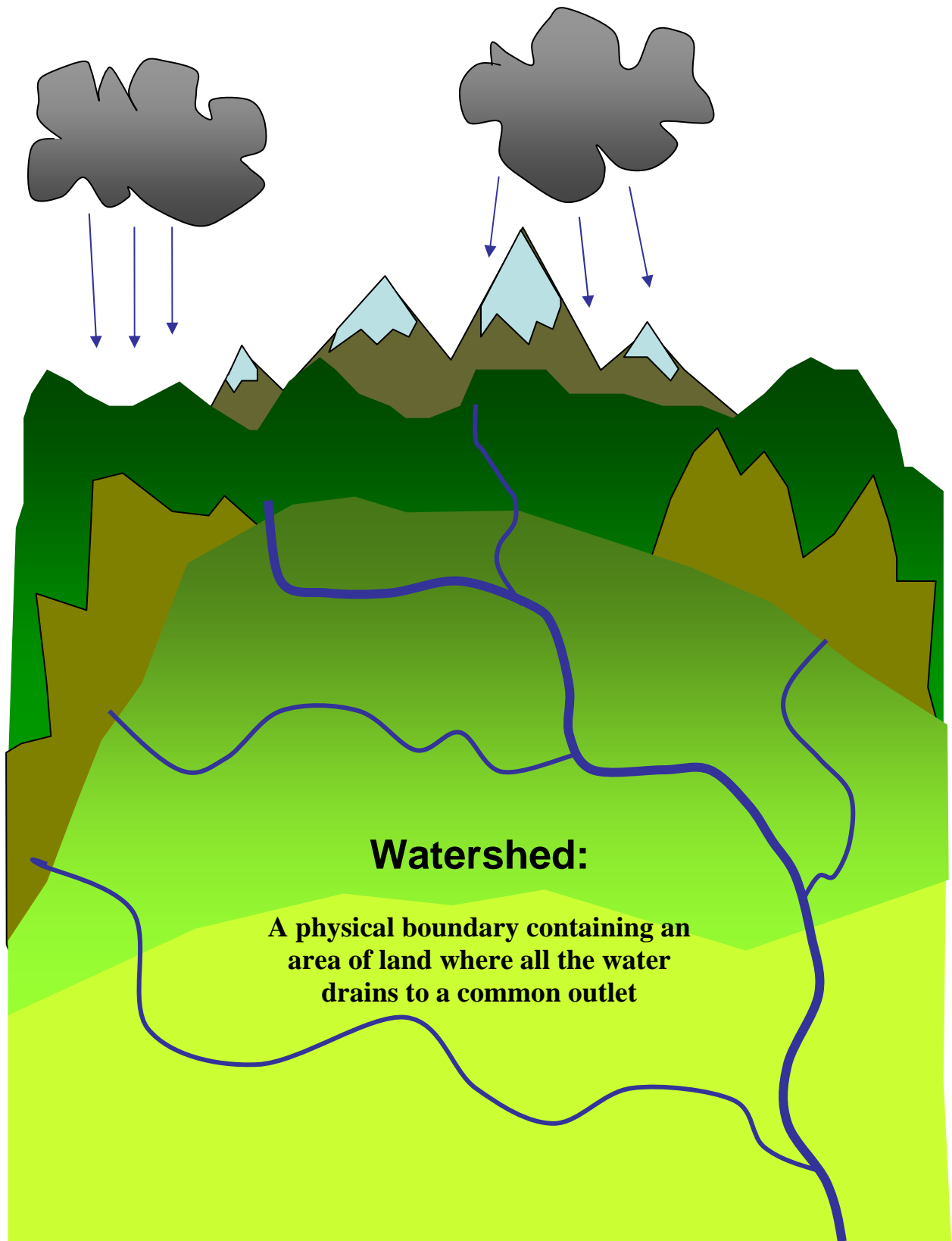
Answer the following questions based on the graphed data:

- 1) How often does below average rainfall occur?
- 2) Does it occur in consecutive years?
- 3) How often was rainfall above average?
- 4) If above average or below average rainfall occurs on a regular basis, is it a normal event?
- 5) Can we expect drought to happen again in the future? Why?

## Activity 2: Average Rainfall Graphs







## **Vulnerability to Drought in the Santa Cruz Watershed**

**Compare these two families who live in the Santa Cruz Watershed:**

### **Rural Family**

Mr. and Mrs. Smith are farmers that have property along the Santa Cruz River. They have a medium sized farm where they grow pistachio nuts and apples. In addition they have five horses on their property, which roam freely to graze. Because they are farming in a dry climate, Mr. and Mrs. Smith depend on irrigation water from the Santa Cruz River. The crops that the Smith's grow and sell are their main source of income.

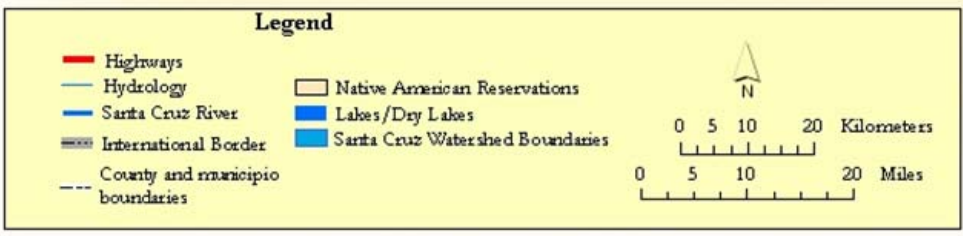
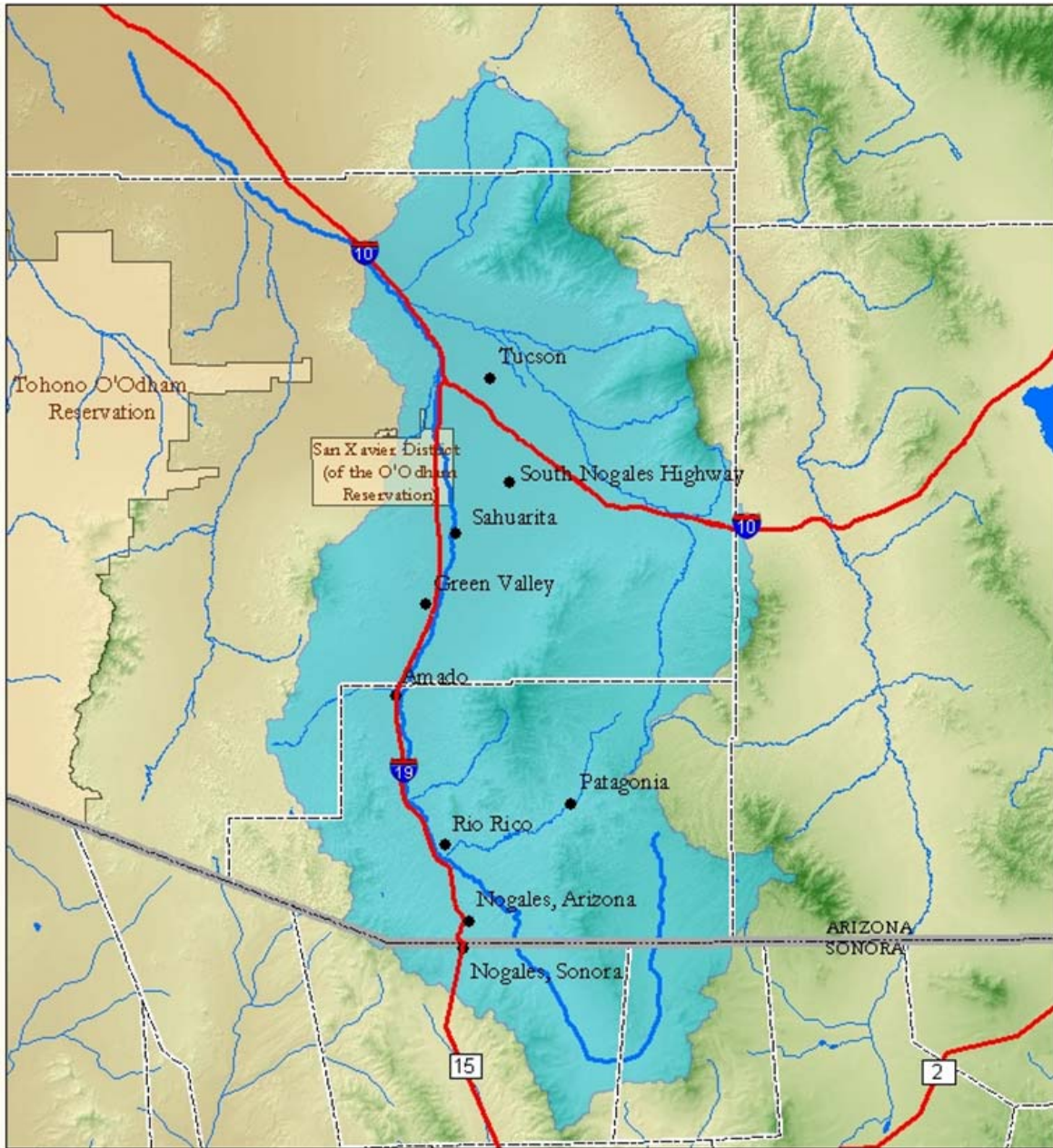
### **Urban Family**

Mr. and Mrs. Garcia live in Tucson with their two children. They live in a house with a yard near the center of town. Mr. Garcia is a teacher and Mrs. Garcia manages a restaurant. In their spare time, Mr. and Mrs. Garcia like to garden. They have a vegetable garden and a variety of non-native plants that need to be watered frequently. They have a lawn in the front yard and a pool in the backyard. Their water is supplied by the city of Tucson.

**Answer the following questions in your drought diary:**

- 1) What natural resources does each resident depend on?
- 2) What are the main uses of water for each family?
- 3) Who probably uses more water? Why?
- 4) Which family's job depends on the climate of Arizona?
- 5) If there were a long drought, how would each family be affected?
- 6) If there were a long drought, which family would be affected more? Why?

# Santa Cruz Watershed



Map composition by Jodi Penin, Center for Applied Spatial Analysis, University of Arizona, 4/7/2003

## **The Santa Cruz River**

The Santa Cruz River's headwaters start in the Patagonia Mountains in Southern Arizona. The river then runs south into Sonora for a span of roughly 30 miles in which it makes a u-turn and then heads north back into Arizona. The river continues north passing through both urban and rural areas and then joins with the Gila River near Phoenix. The political border that divides the river's course has created difficulties for water users of two different nationalities.

Over the years, the Santa Cruz River has been the lifeblood of many people. Prior to European colonization, native populations lived along the Santa Cruz River and practiced irrigated agriculture. Human populations were practicing irrigated agriculture beginning in 8,000 B.C. to 150 A.D. These early farmers were followed by the Hohokam, who prospered until 1450 A.D. The Hohokam are considered the ancestors of the Tohono O'odham, who still live in the Santa Cruz watershed today. The indigenous people used water from the Santa Cruz River to grow corn, beans, squash and cotton. The Tohono O'odham were known to practice a farming technique in which seeds are planted in the floodplain after the spring floods have subsided. In the late 17<sup>th</sup> century, missionaries arrived in the Santa Cruz Watershed. Missionary communities were built up along the Santa Cruz River at the site of indigenous villages. The missionaries introduced Old World livestock and crops such as wheat, barley, and fruit trees.

From the time of missionization to the mid 20<sup>th</sup> century, much of the Santa Cruz Watershed remained a rural area, with the majority of local residents involved in farming, ranching, and mining. Since the 1960's, the border area has experienced rapid industrial and urban growth. This growth depends on the water resources of the Santa Cruz River.

### **Sources:**

Glennon, Robert. 2002. *Water follies: groundwater pumping and the fate of America's fresh waters*. Washington: Island Press.

Logan, Michael. 2002. *The lessoning stream: an environmental history of the Santa Cruz River*. Tucson: University of Arizona Press.



## **Drought Across Borders**

### **Setting:**

The binational Santa Cruz Watershed in Arizona and Sonora.

### **Climate Scenario:**

Southeastern Arizona and northern Sonora are in the midst of a long-term drought that has already lasted five years. The drought is expected to last five more years. The drought has resulted in reduced rain during the winter. The decrease in rain has led to less surface and ground water in the Santa Cruz Watershed. Nogales, Sonora and Nogales, AZ both depend on the water from the Santa Cruz Watershed to supply water to their local residents, businesses, and industry. The drought has put added stress on the already limited supply of water in the Santa Cruz Watershed.

### **Drought Dilemma, Part I:**

Nogales, Sonora is experiencing water shortages and is struggling to provide water for all its residents, businesses, and industry. The drought has caused the wells in the Santa Cruz River to dry up. The city is depending on water from outside the Santa Cruz Watershed and has imposed water restrictions.

Across the border, in Arizona, Nogales and the surrounding communities are still able to meet all their water supply needs. In the Santa Cruz Watershed, Nogales, Arizona has larger aquifers (meaning more groundwater storage) than Nogales, Sonora. Nogales, Arizona also has groundwater recharge from treated wastewater both from Nogales, Arizona and Nogales, Sonora. Therefore, Nogales, Arizona has more surface water and groundwater than Nogales, Sonora. Nogales, Arizona also has a much smaller population than Nogales, Sonora.

### **Discussion Questions:**

1. Should Nogales, Arizona share water with their neighboring town across the border? Why or why not?
2. Should Nogales, Arizona and Nogales, Sonora manage their water together or separately? Why?
3. Could water conservation be used to help solve this problem? If so, how?
4. Should water conservation only occur during a drought period, or at all times? Why?

### **Drought Dilemma, Part II:**

The Santa Cruz River is a river habitat that supports threatened wildlife and is an important corridor for migrating species such as birds. Although the Santa Cruz River is dry in some areas, there is a constant flow of water downstream of the wastewater treatment facility, which is located in Arizona. This constant flow of water creates an important river habitat that supports a number of plants and wildlife. Because of the climate change and drought, there is less water within the Santa Cruz River, and there is more pressure to withdraw water downstream of the wastewater treatment facility. If water is not saved for the river ecosystem, the many bird and fish species will suffer.

**What's the Solution?**

Now pretend you are part of a community watershed group. As a group, devise a campaign to protect the river species. Plan one community event to raise awareness about protecting the river species. To plan the community event, determine the following:

- Who do you want to attend?
- How will you get those people to attend?
- What will you do at the community event?
- How will you get community members to help protect the river species?

Write a one page proposal that outlines your community event.

**Drought Diary Question**

Write a one page response to the following questions.

Should the residents of Nogales, Sonora be concerned about preserving the riparian area in Arizona? Why?

Should residents in Nogales, Arizona conserve water when Nogales, Sonora is having a water shortage? Why?

**Calculate Your Family's Weekly Water Use!**

<b>Activity</b>	<b>Water Use</b>	<b>Calculate Weekly Use</b>
	<b>Amount of water used for each activity</b>	<b>For each activity, multiply the # of gallons per day by the # of times the activity is done per day. The number of times per day should include all your family members.</b>
<b>Bathroom</b>		
Washing Hands	.25 gallons (.95 liters)	Example: $.25 \times 10 = 2.5$
Brushing Teeth	1 gallon (3.8 liters)	
Flushing Toilet (low flow)	1.6 gallons (6 liters)	
Flushing Toilet (other model)	5 gallons (19 liters)	
Showering	30 gallons (114 liters)	
Taking a Bath	40 gallons (151 liters)	
<b>Kitchen/Laundry</b>		
Washing Dishes (By hand)	10 gallons (38 liters)	
Washing Dishes (By machine)	15 gallons (57 liters)	
Laundry (per load)	30 gallons (114 liters)	
<b>Outdoors</b>		
Washing Car	20 gallons (76 liters)	
Watering lawn or garden (30 minutes)	240 gallons (908 liters)	
<b>Food/Drink</b>	.5 gallons (1.9 liters) per day	
<b>Other</b>		
	<b>Total Water Use</b>	

Adapted from National Geographic Society, Geography Action:  
[http://nationalgeographic.com/geographyaction/rivers/ax/PDF1\\_WaterTally.pdf](http://nationalgeographic.com/geographyaction/rivers/ax/PDF1_WaterTally.pdf)