SPLASH: The Student-centered Program for Learning about Semi-arid Hydrology

Core Module 1 - Introducing Southwestern Water Literacy: Society, Cycles and Sustainability

Produced by SAHRA: The NSF Science and Technology Center for Sustainability of semi-Arid Hydrology and Riparian Areas

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I. INTRODUCTION

Core Module 1 - Introducing Southwestern Water Literacy: Society, Cycles and Sustainability

Until we get thirsty we rarely think about water because, like the air that sustains our breath, we take it for granted. Regulation, control, and distribution of water resources insulate us from natural cycles of water abundance and scarcity in the Southwestern United States. This insulation leads to the perception that water is available in limitless quantities. This core study unit offers to challenge these perceptions while building a sound basis for water literacy. In addition, this module serves as a pathway connecting you to more in-depth studies through the six other modules.

Issues surrounding the access and use of water resources are global in scale. Within that context Southwestern Water Literacy: Society, Cycles and Sustainability is a module designed to focus on the American Southwest, a region of relatively scarce water resources with very high population growth. As population increases in this region of limited water resources, sustainability will become increasingly difficult to achieve. Explosive growth in the hottest and driest part of the country is leading to rapid groundwater depletion. The recent US Department of the Interior report Water 2025 (http://www.doi.gov/water2025/) provides an excellent introduction with graphics to some of these issues.

Given these challenges, this module is vital to the high school curriculum. It will accomplish at least two important purposes: Increase water literacy among high school students and allow students a meaningful way to master important state academic standards.

Module 1 functions as the introduction to the other modules. The primary purpose of this module is to stimulate student interest in pursuing one or more of the other modules. In addition, this introductory unit will help students develop a solid understanding of water through multidisciplinary inquiry. In particular, students will gain these three important understandings about water in their lives: (1) the vital role that water serves in human society, (2) the global water cycle and water’s role in energy transfer, and (3) the basic physical and chemical properties of water.

In conclusion, this module seeks to arouse student curiosity about the centrality of water so that they will ask questions that will expand their inquiries. This study unit begins with students’ current understandings in order to generate a personal need to know. At the teacher’s discretion, at any point during the module students may seek answers to deeper questions found in the six additional modules. Every effort has been made to design this module so that it functions as the hub, a place from which to begin and to return.
# SPLASH Module 1: Southwestern Water Literacy

## Core Module 1-Introducing Southwestern Water Literacy: Society, Cycles, and Sustainability

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III. OVERVIEW AND DESCRIPTION OF MODULE 1

Topic 1- The Importance of Water in Human Society

Enduring Understandings:
1- Water is essential to our lives and wellbeing.
2- Human societies significantly impact the water cycle globally and locally.
3- Increasing human demand in our region places increasing pressure on water storage and delivery systems

Essential Question:
1- What is the dynamic relationship between human society and the global water cycle?

Knowledge and Skills:
1- Students will be able to explain how the development of human societies in the Southwest has shaped the use and delivery of water resources.
2- Students will predict how increasing human demand will impact the availability and utilization of water resources.

Topic 2- Global Water and Energy Cycling

Enduring Understandings:
1- Water is fundamental to the dynamic global distribution of heat energy.
2- Seasonal weather patterns in the Southwest impact our quality of life

Essential Question:
1- What is the connection of the global water cycle to seasonal weather patterns in the Southwest?

Knowledge and Skills:
1- Students can describe the movement of water in the water cycle and give a basic accounting of how much water is partitioned into each pool.
2- Students will be able to explain seasonal patterns in weather and climate with the monsoon as a case study

Topic 3- The Basic Physical and Chemical Properties of Water

Enduring Understanding:
1-The physical properties of water apply to both living and non-living systems.

**Essential Question:**
1- What characteristics of water are fundamental to the global water cycle?

**Knowledge and Skills:**
1- Students will be able to use the commonly accepted model of water’s molecular structure to explain the heat capacity of water as it relates to molecular structure, hydrogen bonding, and heat capacity.
2- Students will use the knowledge of water’s molecular structure and heat capacity to explain the presence of water in the 3 phases of water in the global water cycle.

Section IV provides a short pre-assessment of the water cycle to enable the teacher to have a clearer idea of their students’ knowledge base. It becomes the opening lesson, introducing this unit and creating a reason for studying about water. This section also includes a cumulative assessment that can be used at the end of the module. The teacher is reminded that the SPLASH introduction includes direction for assessment throughout the modules.

**VI. ASSESSMENT**

**Pre-Assessment - Why do we need to know more about water?**

**A. Objective:** Students will understand why they should know more about water and how it shapes their lives.

**B. Lesson Overview:**
The teacher can use the Pre-assessment to also establish the opening track towards improving student water literacy. This section is divided as follows: 10 Multiple Choice questions followed by a suggested script. It is organized to take one class period, and can easily be adapted as the teacher desires.

**C. Materials / Resources Needed:**
- **Teacher:**
  - Overhead projector or PowerPoint
  - Photocopy of the Pre-Assessment for each student
  - One or two blank transparencies or white/chalk board
- **Student:**
  - One or two sheets of notebook paper

**D. Instructions:** Have students answer the following questions.
Multiple Choice

1. Most of the southwestern U.S. is classified as sub-humid because
   A. it is mostly desert
   B. it has two seasons, one long dry one and another one for three months called the monsoon.
   C. because it receives less than 20 inches of precipitation per year.
   D. it is hot much of the year.

2. A basic fact to understand about water is that
   A. it is central to life.
   B. it has the same properties as do almost every other substance.
   C. like most every other compound it has three states that become increasingly more dense: gas ("water vapor"), liquid ("water"), and solid ("ice").
   D. all of the above are correct.

3. Daily water consumption within a household of four people in the Southwest averages about
   A. 100 gallons.
   B. 250 gallons.
   C. 700 gallons.
   D. 1,200 gallons.

4. For residents of the Southwest water is most frequently priced
   A. on the basis of scarcity.
   B. much higher than what people pay east of the Mississippi.
   C. according to seasonal demand.
   D. so that the costs of supplying it, especially to transport and treat, it are recovered.

5. Over the past half century human interaction with the Southwest water cycle has been increasingly determined by what factor?
   A. irrigation for agriculture.
   B. urbanization.
   C. global warming.
   D. federal policies.

6. When water evaporates
   A. it is temporarily removed from the water cycle.
   B. heat energy is stored and later released when it rains.
   C. rain will soon follow.
   D. we feel "hotter" because our skin feels dryer.
7. Water cycling in the Southwest
   A. is unique because of the monsoon.
   B. acts independently from the global water cycle.
   C. reflects the unchanging climatic pattern, typical of semi-arid areas.
   D. none of the above.

8. Which of the following statements best states the historic pattern that links the different societies that have inhabited the Southwest?
   A. Generally the most continuously inhabited areas have had access to water at or very near the surface.
   B. People depended on trade, minerals for food, because very little agriculture was possible until modern irrigation techniques were developed in the late 19th century.
   C. Populations were small until the mid 20th century, living in villages instead of urban communities.
   D. All human groups have had to practice irrigation in order to survive in this region.

9. Surface water and groundwater
   A. are the same.
   B. are independent of one another.
   C. reflect only recent climate conditions.
   D. are important parts of the water cycle.

10. Living as we do at the beginning of the 21st century we need to know more about water because
   A. we are definitely running out of water.
   B. the climate is warming and thus less rain has been falling around the world including the Southwest.
   C. we live in the Southwest.
   D. present water use in the Southwest and much of the world threatens the sustainability of future human societies.
Answers

1. The teacher may choose to give the pre-assessment formally or informally. The script that follows can be adapted to either method. An overhead projector with prepared and blank transparencies may be used when the answers to the questions are explained. As explained the introductory information provided in Section 1 above may be incorporated into this opening learning activity.

2. **QUESTION 1, ANSWER is C** It is important to understand that we live in an area that is deficient in rainfall as a normal pattern. The Southwest is part of a larger global area that encompasses 1/3 of the earth’s land mass and currently experiences rapid population growth. For the communities in the Southwest, much of this population is coming from more humid areas, and many try to re-establish lifestyles consistent with areas that receive more than 20 inches of rain per year, which includes having lawns and high water use plants. Much of the Southwest receives less than 20 inches of precipitation annually, and thus is semi-arid, and in the driest portions where less than ten inches falls each year, is classified as arid.

   In introducing these terms (**humid**, **semi-arid**, and **arid**) the teacher may want to have them listed on a viewing screen or white board, or have a photocopy that includes this information as the pre-assessment questions are reviewed.

3. **QUESTION 2, ANSWER is A:** Water is the central ingredient of life. Almost 2/3 of the human body is composed of water, and we could not last more than a week without water. As you will learn, water has unique properties that affect both the quality and the abundance of life.

4. **QUESTION 3, ANSWER is C** It is extremely difficult to generalize about the average consumption of water in the home because it varies from place to place across the Southwest and even from season to season. The important point, however, is that we use more water than most of us realize. This estimate breaks down to about 175 per person. Imagine if you needed to store this water daily; that would mean filling up two huge refrigerators (26 cubic feet each) for each person!

   The amount of water that we use is too frequently wasted or used unwisely, and in many respects should be considered excessive for a relatively dry climate region. One of the learning activities that we will do examines the various parts of the home where water is used and includes ways to practice conservation. One other thing; you may also be interested to know that this estimate given for this question is only for direct use. When we include the manufactured items in our home and the processed food that we eat, each of us uses millions of gallons of water every year. For example, it takes roughly 139 gallons of water to produce the ingredients in just one medium slice of cheese pizza.

5. **QUESTION 4, ANSWER is D** Many people have asked the question, why they have to pay for water when they don't pay for the air that they breathe? As we will see when we examine the rate structure on a sample water bill, many factors make it necessary to charge people for the water they use, especially transport and treatment costs. For now, remember this. Water weighs 8.34 pounds per gallon and it mostly has to pumped against gravity in order to reach your taps. (You might want to ask students to do a quick calculation about the weight of the daily water use per person from question 4 above.) As we go deeper into the ground for water and also transport water in open canals for many miles, it has to be treated for impurities and checked for toxicity. Once we use it, it has to be re-transported through the sewers, and because our society is trying to recycle water in greater
amounts, has to be retreated. As you will see, the water that we receive in our homes is inexpensive, a real bargain. [You might choose to open the discussion at this point to allow students to think about whether water should be more expensive as a way to encourage conservation.]

6. **QUESTION 5, ANSWER is B.** The Southwest is surprisingly (it would seem to many at least) the most urbanized part of the United States. Consider this fact from above. For each new person who chooses to move to the Southwest, we can expect the demand for water to increase by as much or even more than 175 gallons per day. [You might offer to do or have them do some quick math. Use your local area and apply the current population increase. For the Tucson metro area of 850,000 people, the growth rate is at least 2% per year.] At this point, too, you might want to explain that while agriculture has historically used the most water, even though its proportionate use is dropping that difference is being exceeded by urbanization. [Depending on time and purpose, you might also want to have students consider how urbanized life separates us from the natural. Would we think differently about water if we had to go to our own well and carry it back by the bucket full?]

7. **QUESTION 6, ANSWER is B.** The water cycle is an essential part of the process of heat transfer, which makes life possible. Evaporation is part of this process. Not only does it make rain possible, but as water is converted to vapor, the energy stored within it is later released when It is suggested that you hold off on introducing the water cycle until students have completed the Southwest Water Cycle inquiry included in this module.

8. **QUESTION 7, ANSWER is D.** Water cycling in the Southwest represents a variation of the global water cycle due to local conditions. Quite simply in a drier region less water moves through the cycle. But in other important respects, the it is the same as other regional cycles and the global water cycle. You must appreciate the concept of interdependency to understand the water cycle here or for any other region. In the Southwest, the summer monsoon offers the most dramatic period of what we perceive as an active period of our water cycle. Some years are "wet" and others relatively "dry." We will study the monsoon and you will begin to understand how conditions outside of the Southwest interact with local factors to determine what kind of monsoon season we experience. You will also learn how the less dramatic winter rainy season is actually more critical to our water cycle and in creating and sustaining our water resources.

9. **QUESTION 8, ANSWER is A:** Since water is essential to life it should come as no surprise that its availability has been a strong determinant affecting human lifestyles in the Southwest. Societies living here before ours over the past century have had to be self-sufficient in producing foodstuffs. Not all peoples practiced irrigation, but most did. Our interdependency with other US regions and the global economy has presently eliminated our need to for self-sufficiency, but our dependency on local water resources only grow as we increase our demands on them.

10. **QUESTION 9, ANSWER is D:** Not only are surface and ground water important parts of the water cycle but are interdependent. An old saying goes that "what you see is what you get." When it comes to water supplies that can be adapted to include what you don’t see as well. Over 50% of the water consumed in the United States is groundwater. In the Southwest that percentage is often higher, but no matter where, the evidence is clear: When large amounts of groundwater are mined, the effect is noticeable above ground. Not only can the ground sink (creating "sink holes") because the water that had been supporting it was removed,
but the amount of surface water no longer remains. Tragically much of water law excludes the interrelationship between surface and groundwater. This makes the challenge of increasing the level of water literacy among a larger population all the more crucial.

11. **QUESTION 10, ANSWER is D:** It would be too much to say that we are running out of water. As much water exists today as it did thousands of years ago. However, more of us want it and depend on it in so many ways. Today, an estimated two billion people around the world (one out of every three humans on earth) do not have daily access to clean drinking water. This problem continues to grow and in our interdependent world, cannot be ignored. People have fought and died over access to water. As we study this module keep in mind that the world that you will live in as adults will be increasingly challenged to use water wisely. Many decisions will have to be made, some of them extremely tough and controversial. The more that you know about water, the more you can make a positive difference.

12. If you wish, the following basic term/concepts can be introduced and/or reintroduced. They can be added to the Pre-assessment and then discussed, or instead introduced and explained.
   b. Aquifer: The area underneath the earth's surface that collects and stores water.
   c. Recycle: To use again and again; the water cycle represents this process.
   d. Watershed: The drainage area of a primary river within which all surface water flows in supporting streams, creeks and washes.
   e. Sustainable: Able to continue on indefinitely.
   f. Climate: Atmospheric conditions, especially periods of wet and dry, that characterize a region such as the Southwest over many years establishing a pattern such as semi-arid.
   g. Weather: Atmospheric conditions existing for the short term, such as a day.

13. **Closure:** Check for questions. Ask students either orally or in writing to state one important fact learned today. In addition, ask them to write down at least one question that they want answered about water in their research logs.
Basic Assessment for Core, Module 1

Section One: Multiple Choice

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    C. we live in the Southwest.
    D. present water use in the Southwest and much of the world threatens the sustainability of future human societies.

11. Which of the following devices uses the greatest amount of water?
    A. the toilet.
    B. the dishwasher.
    C. the shower.
    D. the washing machine.

12. A water bill will indicate monthly water use in ccf, where 1 ccf is the equivalent of how much water?
    A. 50 gallons.
    B. 748 gallons.
    C. 1000 gallons.
    D. 2153 gallons.
13. Juan takes a ten-minute shower. If he uses a standard showerhead, his shower consumed roughly how many gallons of water?
   A. 50 gallons.
   B. 27 gallons.
   C. 5 gallons
   D. 3 gallons.

14. The culture group that demanded most from the water resources of southern Arizona prior to 1880 was
   A. the Spanish.
   B. the Mexicans.
   C. the Hohokam.
   D. the Tohono O'Odham.

15. What is the least correct statement about modern water delivery systems?
   A. They support the trend to urbanization in the Southwest.
   B. They are inexpensive and easy to create.
   C. These systems received a big boost with the passage of the National Reclamation Act in 1902, which introduced massive federal funds.
   D. These systems do not include the mining of water.

16. The North American Monsoon
   A. is not part of the water cycle because it is a rather unique local event.
   B. offers more to the quality of life in the Southwest and less to the quantity of water than is often assumed.
   C. is regular, and predictable as to when it arrives, how it will act, and when it departs.
   D. refers to the thunderstorms that it creates due to the seasonal period of intense summer heat.

17. A primary moisture supply to create the North American Monsoon is
   A. the Gulf of Mexico.
   B. the Colorado River.
   C. the Pacific Ocean.
   D. the Great Lakes.

18. Plow winds and "gustnadoes" can be conceived as relating directly to
   A. local topographical conditions.
   B. the amount of rain that falls in a thunderstorm.
   C. "dry thunderstorms"
   D. energy stored when water evaporated.
19. The important properties of water that affect life include
   A. it is a rather simple molecule that acts in complex ways.
   B. it remains in liquid form at a greater range of temperatures than is common for other
      substances.
   C. water actually become less dense in its solid state.
   D. all of the above.

20. Water covers 75% of the earth, but what percentage of all the water on earth is available
    to us?
    A. about .4%.
    B. about 2.5%.
    C. about 10%.
    D. at least 25%.

Section Two: Short Answer
Provide a brief definition for each of the following and identify its relationship to the
Southwest Water Cycle.) NOTE: The teacher can decide to reformat these so that students
 can write their answers on the test, and determine their point value in relation to the entire
assessment.

21. Hydrology
22. Transpiration
23. Water Flow
24. Recharge
25. Sustainable
26. Aquifer
27. Semi-arid
28. Watershed
29. Urbanization
30. Water table

Section Three: Articulation
31. Imagine that you were asked to make a presentation to a county planning commission
    examining the question of how best to educate the public regarding water use and water
    supply. For this assessment you have a choice of making this presentation in either of
    the following ways: 1] as a written report of about 500 words, or 2] as a poster or chart.
    Whatever presentation is used must illustrate a clear understanding of the primary issues
    involved along with a good conceptual understanding of the essential facts about the
    Southwest Water Cycle and human interaction with it.
Answers

Note: The answers with explanations for questions 1-10 are provided with the Pre-assessment.

11. **ANSWER, is D:** Automatic clothes washing machines account for about 20% of total water use in the home.

12. **ANSWER is B:** Ccf is the abbreviation for "hundreds of cubic foot of water;" 1 cf = 7.48 gallons

13. **ANSWER is A:** A standard showerhead can use up to 5 gallons per minute

14. **ANSWER is C:** Before more intense cultivation by Whites following the American Civil War no group had developed the kind of engineering that allowed for extensive agriculture supporting relatively dense populations than did the Hohokam over 800 years before.

15. **ANSWER is D:** Modern water delivery systems rely extensively on pumping or mining of ground water, which is also transported to the various water users.

16. **ANSWER is B:** The North American Monsoon is a seasonal wind shift (from which it gets its name) that interacts with local conditions. While huge amounts of rain can fall, much of it runs off so that less proportionately percolates to recharge the aquifer than slower, steadier winter rains and snow. However, because it is a relief from the intense heat, its psychological benefits are huge, affecting the quality of life.

17. **ANSWER is A:** The National Weather Service refers to this seasonal event as the "Mexican Monsoon" created by a larger hemispheric pattern during the summer when the mid level winds shift to the southeast bringing up moisture form the warm waters of the Gulf of Mexico and/or the Gulf of California. Rain that falls during this period is recycled into the atmosphere and available for addition precipitation in the region when new storms develop.

18. **ANSWER is D:** The key conceptual understanding here is the water cycle itself. Evaporation is a key part of this process where as water is lifted and converted to vapor, latent heat energy is stored and later released to help generate a storm's energy. Local topographical conditions can interact with these storms, but the original source of energy that creates these winds emanates from the evaporation process.

19. **ANSWER is D:** Water has all of these characteristics.

20. **ANSWER is A:** What is surprising to most people is how much water exists on earth and how so little of it is available to us.

**Section 2: the definitions are not provided here, but brief references to the water cycle for each are provided to aid in the teacher's evaluation.**

21. **Hydrology:** Although normally understood as focusing on groundwater, this science is the study of the water cycle becoming the path to water literacy.

22. **Transpiration:** Plants release significant amounts of water into the atmosphere available to be recycled to the earth as precipitation.

23. **Water Flow:** When precipitation falls water makes its way eventually to the oceans either above or below the ground, to be evaporated and later fall as precipitation.

24. **Recharge:** Water that makes its way into the ground after falling as precipitation becomes an important water resource for us.

25. **Sustainable:** Understanding the dynamics of water cycling facilitates a better understanding of concerns over sustainability.
26. Aquifer: This natural storage area temporarily withholds water from the water cycle in the sense that instead of more swiftly flowing back to the ocean as it would above ground, water becomes available for human beings to pump out ("mine") of the ground.
27. Semi-arid: In the Southwest, because a smaller proportion of water flows through the water cycle than in humid areas.
28. Watershed: This drainage area supplies most of the water used locally from both above and below the ground.
29. Urbanization: Roofs, concrete, etc, interfere with the natural flow of water through the hydrologic cycle.
30. Water table: This top layer of water in the aquifer acts as a barometer to indicate the extent of water use.

Section Three: Articulation
Assessment should include: the primary issue is sustainability in a semi-arid region; this might be illustrated to include human interaction to indicate urbanization and its effect on the water cycle. The key parts of the water cycle should be included, especially evaporation, transpiration, percolation and water flow. Students should display an understanding of this relatively continual flow (or motion) that recycles water over time and how human demand and actions affect it. The SPLASH introduction includes guidance on assessing student presentations.

Section V identifies the many Arizona Academic State Standards that can be taught throughout Module 1. This illustrates the multi-curricular potential of this introductory inquiry for Southwest Water Literacy.

V. ARIZONA ACADEMIC STANDARDS APPLICABLE TO MODULE 1

SCIENCE STANDARDS

ISC-P5. Apply the Concepts of Equilibrium, form and function to a variety of phenomena
PO-1. Predict the effects of various, factors on the equilibrium of a system
PO-2. Explain how the relationships between form and function are evident in natural and designed systems
PO-3. Describe how present form and function of an object, organism or system could have evolved from prior form and function
3SC-P4. Identify and describe the basic processes of the natural ecosystems and how these processes affect, and are affected by, humans
PO-1 Describe the basic processes of the natural ecosystems (e.g. water cycle)
PO-2 Explain how these processes affect, and are affected by, humans
4SC-P6. Describe and explain the cycling of matter and the flow of energy through the ecosystem's living and non-living components
PO-1. Explain the relationships among abiotic and biotic components of an ecosystem in terms of energy flow and the cycling of matter
5SC-P6. Describe and explain physical interactions of matter and energy, using conceptual models
PO-1. Demonstrate the use of conceptual models in science.
PO-2. Describe physical interactions of matter and energy
PO-3. Justify the validity of known conceptual models applied to physical phenomena
MATH STANDARDS

STANDARD 2: DATA ANALYSIS AND PROBABILITY
Students use data collection and analysis, statistics, and probability to make valid inferences, decisions and arguments and to solve a variety of real-world problems.

2M-P1. Construct and draw inferences including measures of central tendency, from charts, tables, graphs and data plots that summarize data from real-world situations
PO 1. Organize collections of data into frequency charts, stem-and-leaf plots, scatter plots.
PO 3. Draw inferences from collections of data
PO 4. Evaluate the reasonableness of conclusions drawn from data analysis
PO 6. Identify graphic misrepresentations and distortions of sets of data

2M-P2. Use appropriate technology (e.g., graphing calculators, computer software) to display and analyze data
PO 1. Use appropriate technology to display data as lists, tables, matrices and plots
PO 3. Use appropriate technology to predict patterns in sets of data

2M-P5. Design and conduct a statistical experiment to study a problem and interpret and communicate the outcomes
PO 3. Organize collected data into an appropriate graphical representation
PO 4. Draw and support inferences that are based on data analysis

STANDARD 3: PATTERNS, ALGEBRA AND FUNCTIONS
Students use algebraic methods to explore, model and describe patterns, relationships and functions involving numbers, shapes, data and graphs within a variety of real-world problem solving situations.

3M-P1. Model real-world phenomena (e.g., compound interest or the flight of a ball) using functions and relations (e.g., linear, quadratic, sine and cosine, and exponential)
PO 2. Describe a real-world situation that is depicted by a given graph
PO 1. Identify the independent and dependent variables from a real-world situation
PO 3. Sketch a graph that models a given real-world situation

4M-P2. Represent and analyze relationships using written and verbal explanations, tables, equations, graphs and matrices and describe the connections among those representations
PO 3. Determine whether a relation is a function, given the graphical representation
PO 1. Express the relationship between two variables using a table, equation, graph and matrix

STANDARD 5: MEASUREMENT AND DISCRETE MATHEMATICS
Students make and use direct and indirect measurement, metric and U.S. customary, to describe and compare the real world and to prepare for the study of discrete functions, fractals and chaos which have evolved out of the age of technology.

5M-P1. Represent problem situations using discrete structures such as finite graphs, matrices, sequences and recurrence relations
PO 1. Use matrices and finite graphs to display data

5M-P2. Represent and analyze finite graphs using matrices
PO 1. Interpret data using matrices and finite graphs (e.g., networks, street diagrams, tournament schedules, production schedules)
PO 2. Determine when a finite graph gives an accurate picture of a data set
PO 3. Translate a finite graph into a matrix and vice versa

LANGUAGE ARTS STANDARDS

R-P1. Apply reading strategies such as extracting, summarizing, clarifying, and interpreting information; predicting events and extending the ideas presented; relating new information to prior
knowledge; supporting assertions with evidence; and making useful connections to other topics to comprehend works of literature and documents

W-P2. Write a persuasive essay (e.g., an editorial, a review, an essay, a critique) that contains effective introductory and summary statements; arranges the arguments effectively; and fully develops the ideas with convincing proof, details, facts, examples and descriptions

W-P4. Craft a cohesive research document that develops a logical argument or thesis; contains comprehensive, supporting information from a variety of credible and cited resources; and conforms to a style manual

LS-P3. Deliver oral interpretations of literary or original works

LS-P4. Conduct an interview, taking appropriate notes and summarizing the information learned

LS-P5. Evaluate the effectiveness of informal and formal presentations that use illustrations, statistics, comparisons and analogies

SOCIAL STUDIES

1SS-P1. Apply chronological and spatial thinking to understand the meaning, implications, and import of historical and current events.

1SS-P2. Demonstrate knowledge of research sources and apply appropriate research methods, including framing open-ended questions, gathering pertinent information, and evaluating the evidence and point of view contained within primary and secondary sources.

1SS-P12. Analyze the development of the American West and specifically Arizona

1SS-P18. Apply the skills of historical analysis to current social, political, geographic, and economic issues facing the United States

3SS-P3. Analyze how economic, political, cultural, and social processes interact to shape patterns and characteristics of human populations, interdependence, and cooperation and conflict

3SS-P4. Analyze the interactions between human activities and the natural world in different regions, including changes in the meaning, use, distribution, and importance of natural resources

3SS-P5. Apply geographic knowledge of people, places, and environments to understand the past and present and plan for the future
IV. LEARNING ACTIVITIES

General Introduction

You will have already noticed some organizational features in the presentation of this material. Highlighted boxes are intended to provide a quick overview to facilitate your planning and to allow you to move freely throughout the Core. Learning Activities are described in some detail with brief concluding assessments.

Go To: One purpose of the “Go To” is to save paper by having students go directly to a website, leaving you the option as to what you will need to have reproduced. In addition, many websites will use different colors for text emphasis, and typically have color diagrams, photos, drawings, charts, etc. that often make reproducing them cost prohibitive. You may want to print a class set of the information from the various websites listed if you have limited computer availability. You may also want to print a small number of copies for students who are absent and/or who do not have home computers. Students with home computers could be supplied a list of the URLs. You may choose to print color overhead transparencies if your students will not be at a computer during the classroom learning sessions.

Research Log: You will want to have students keep a Research Log throughout the core module. If this option is available, students could do this on a computer in a commonly used word processing program, save it to both a floppy for backup and on the hard drive. The other method of keeping a Research Log would be to use pencil and paper. Composition books might be preferable. One advantage to the composition books is that it would be easy for the teacher to make random checks/award points as the students are working on the computers. Do make the Research Log a part of your grading system and inform the students what you expect and how much of the grade it will represent. The Research Log will help students reflect on where they have been in their quest for information, concepts, etc. In addition, it will ensure active student participation throughout the core module.

There are many ways you can have students use the Research Log. When students go to web pages, they can record the URL and title with a brief description of concepts and information from the website and how they found this site to be useful. They can record information you present in class and experiment descriptions. In many of the inquiries the students will be asked to write a significant enduring understanding learned and this can also be included in the Research Log. Since this study is inquiry based, you might ask students to write a question each day that they want answered and to write what they learned as a result. Students may also find interesting drawings, photos, etc. in their studies that they will want to include in their Research Logs. Inform students they can paste such items into their logs. If photocopying is not readily available, tell the students that if they want to include these items in their Research Logs, they will need to print their drawings, photos, etc at home. A helpful suggestion would be that they do not have to print drawings, photos, etc. at full size, these objects can be printed much smaller yet still be viewable.

You may want to develop a coding system for required and optional websites (optional sites would be ones the students discover with related information). Possibly have students use REQ (required) and OPT (optional) preceding their website listings. You might also want to develop a shorthand for students to record URLs by creating a master listing and labeling your first site visit as Web 1, your second site visit as Web 2, etc. In that way students could list their visits as Web 1, Web 2 in their Research Logs instead of writing out the whole URL.
It is important to emphasize to your students that these activities are built upon the inquiry method. In other words, they should continually question and seek answers to them and to the questions asked during each activity. Encourage students to look for extensions to the material presented in the Core module. Stress creating a “need to know” at the beginning of each task. Since these inquiries are intended to serve as "launching pads" to more in-depth inquiries, it may not be opportune to have them to proceed until you are ready for them to do so. You may want to employ methods such as KWL worksheets (what you already know, what you want to know, and after the task, what you have learned). Stress to your students their need to continually inquire throughout the core module.

The mode of presentation is up to you the teacher. We provide suggestions and often a script. You may be uncomfortable with managing students on 30 computers and may prefer to present the information on a projector linked to your computer. The mode of presentation is left up to you.

SPLASH has created a website for participating teachers. We invite you to make suggestions and to provide feedback. Together we can create a cooperative community of educators who want to make water literacy a vital part of the K-12 curriculum.
Inquiry 1: Personal Water Use Log – *How much water do we use?*

A. **Objective:** Students will be able to explain how they and their families impact water resource consumption and ways that they can practice conservation.

B. **Lesson Overview:**
   Students will be able to learn more about personal water use by using a sample water bill in class. Besides knowing more about the various costs involved in delivering water to the home, students will learn more about how much water is consumed within a household. This opening lesson is designed for approximately a 50-minute class period. The *Homework Assignment* will ask students to apply what they learn by comparing the sample with one from their home and will measure the rate of flow in gallons from several places in the home.

C. **Materials / Resources Needed:**
   **Teacher:**
   - Overhead projector
   - Transparency of Sample Water Bill
   - Photocopies of Fact-finding sheet for student homework assignment
   - One or two blank transparencies or white/chalk board
   **Student:**
   - Homework Assignment Fact-finding sheet
   - One or two sheets of notebook paper

D. **Instructions**

1. The Sample Water Bill can be printed on an overhead transparency and shown to the students so that they understand all the components and terms of their water bill.
2. As the teacher explains the various parts of the sample water bill, students should be informed that while “cf” means cubic feet, “ccf” means hundreds of cubic feet. On the bill 14 ccf is equivalent to 1400 cubic feet. The 1st “c” in front of the cf comes from the Roman “century” or “centurion”, meaning 100.
3. As the teacher explains the numbers relating to use and cost, the information below may be integrated into the lecture, OR the teacher may choose to have the students work calculating the answers to the problems below:
   a. Assume your home has ¾-inch water lines. How much is your service charge? ($5.35)
   b. Assume your water bill shows a usage of 15 ccf for the month. How much will your water usage charge be? ($15.45)
   c. What is your CAP charge for 15 ccf if you are billed $0.03 per ccf? ($0.45)
   d. How much is the sewer administrative charge for a ¾-inch water line? ($2.49)
   e. How much is the sewer usage charge for 15 ccf, if you are paying $1.00 per ccf? ($15.00)
   f. Add the answers for A through E to get your real total cost for 15 ccf of water. (We will ignore the tax for this exercise.) ($38.74)
   g. 15 ccf is equal to how many cf? (1500)
h. One cf is equal to 7.48 gallons. How many gallons of water are equivalent to your cf? (11220)
i. Divide your total cost in step F by your gallon answer in step H to determine your actual cost per one gallon of water. ($0.00345- about 1/3 of a penny per gallon!)

The following statement can be read to the students and discussed. When you go to a grocery store and buy the cheapest water by the gallon, you typically pay about $1.00 for that gallon of water. If you were to fill gallon bottles out of your faucet in your kitchen, you could fill 300 gallon size bottles for the same $1.00!! Why do you think the difference is so large? [Certainly the profit motive is at work here. Water providers such as Tucson Water Company do not function along a chain of supply ending with the retailer. In addition, water supplied to the home carries with it an implied “volume discount,” and does not require individual packaging. Another factor is that the method of transporting tap water is not by truck with loading, unloading and then stocking and restocking at the point of sale.]

4. Students should next be directed to form small work groups of roughly 3 to 4 students. The task for this activity is explained as follows.
   a. Once students have formed their groups have them select a captain.
   b. Instruct them that they have about 15 minutes for completion before returning to a classroom discussion and analysis.
   c. Their task is to calculate both the monthly and the annual household consumption in gallons (give them the figure of 546 ccf for annual consumption) and then calculate this on a household per capita basis for a family of four.
   d. After 15 minutes return to a classroom discussion. Ask students to determine whether or not they believe this is a "typical" water bill or not, and to explain why they think so.

5. After students have worked in their groups for about 15 minutes redirect them to a class discussion.
   a. Call on a group captain to report their per capita consumption calculation.
   b. See how that result compares with those from other groups. (Note: The monthly rate of consumption was 673.2 gallons per day. Per capita consumption was therefore, 168.3 gallons. Their annual rate was 408,408 gallons or 279.73 gallons per capita per day.)
   c. Ask another captain to discuss how typical this family would be. (The Tucson average historically has been about 172 gallons per day.) Ask the class to explain what might cause the monthly fluctuations and why this family has a much higher than average water use.
   d. Ask the class to suggest ways that this family might reduce their water consumption.

6. Instruct students that they are to go home tonight and do the following:
   a. If possible, get a recent water bill and compare their family’s consumption to the sample in class. [This can be offered for extra credit.]
   b. Complete the Home Water Use Worksheet.
   c. Using these results, instruct them that they will calculate how many gallons of water they use to brush their teeth and to take a shower or bath.
   d. Instruct them to complete the sheet and turn it in on the fourth day as a required assignment.

7. Check to see if the students understand their assignment and review the main points learned to today.

E. Materials
Sample Water Bill

**Sewer administrative charge** (based on meter size) that you pay no matter how much water you use; **Sewer usage charge**- basically about $1.00 per ccf.

**Monthly service charge** (based on meter size: a 3/4 inch line is $5.35 - most homes are 3/4 inch lines) You pay this no matter how much water you use. This amount is for meter maintenance & replacement, meter reading, and billing costs.

**Water usage charge**- based on how much water you use, as you use more water the rate per ccf goes up. 1-15 ccf is charged at $1.03, 16-30 ccf is charged at $3.50 (for more detail you can go to: http://www.cityoftucson.org/water/customer_svs/rates/rates.htm)

**CAP charge**- is a flat rate of $0.03 per ccf to help pay the cost of Central Arizona Project (CAP) water which Tucson Water purchases from the Central Arizona Water Conservation District (CAWCD).

1 cubic foot = 7.48 gallons
1 ccf = 100 cubic feet
1 ccf = 748 gallons

April 2002
April 2003

The graph helps you see your water usage over the past year. The vertical axis is in ccf, the horizontal axis is labeled by month.
**Home Water Use Worksheet**

### Fact-finding Sheet to Estimate My Water Use at Home

<table>
<thead>
<tr>
<th>Water Site</th>
<th>Time (seconds) Faucet 1/4 turn</th>
<th>Time (seconds) Faucet 1/2 turn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kitchen sink</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bathroom sink</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bathroom tub</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shower</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outdoor faucet</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Data Sheet to Calculate My Water Use at Home for Various Needs

<table>
<thead>
<tr>
<th>Task</th>
<th>AM: Time = estimated gallon use</th>
<th>PM Time = estimated gallon use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day One: <strong>Brushing Teeth</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day Two: <strong>Brushing Teeth</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day Three: <strong>Brushing Teeth</strong></td>
<td></td>
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</tr>
<tr>
<td><strong>3-Day Trend</strong> in water use: (Up; Down: No Change); Explain</td>
<td></td>
<td></td>
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<tr>
<td>Day One: <strong>Shower/Bath</strong></td>
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<tr>
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<tr>
<td><strong>3-Day Trend</strong> in water use: (Up; Down: No Change); Explain</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The most important understanding about using water more wisely in my home that I have learned from doing these two lessons was:

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**F. Additional Resources**
Do you want to know…how your water use compares with other residential water users?
http://www.cityoftucson.org/water/conservation/usage_comparison/usage_comparison.htm

…how to read your water meter?
http://www.cityoftucson.org/water/customer_svcs/read_meter/read_meter.htm

…current water rates?

G. Extensions

Question students about ways they think they can save water. You might need to stimulate the students with some of the following information:

- A typical bathroom faucet uses up to 3.5 gallons per minute. Installing a faucet aerator can cut that to about 1.2 gallons per minute.
- Turning off the water while brushing your teeth can save 2 or more gallons per brushing.
- Using a sink full of water instead of running the faucet while shaving can save nearly 20 gallons.
- A standard showerhead can use up to 5 gallons per minute. A low-flow showerhead will use about 2.5 gallons per minute. Turning the water off while lathering up with soap can save water.
- Run dishwashers at the most economical setting. Dishwashers use 16 gallons on a pot-scrubber cycle, while using only 9 gallons on a shorter cycle.
- Washing machines can use up to 48 gallons per load. Make sure to wash only full loads, or set the water level to a lower setting if not doing a full load.
- The first use of reclaimed water in Tucson was started in 1984, almost 20 years ago.
- Reclaimed water makes up about 8% of all the water delivered by Tucson Water, with the goal to maintain that 8% figure by expanding reclaimed water use as the population grows.
- The reclaimed water system encompasses 100 miles of pipelines that are operated separately from the drinking water system.
- Reclaimed water is used at more than 600 sites in the Tucson area, including 13 golf courses, 28 parks, and 40 schools (including the University of Arizona and Pima Community College).
- Reclaimed water use saved 3.4 billion gallons of drinking water in 2002. That amount would provide water service for about 31,000 families in Tucson for a full year.
Inquiry 2: Practicing Residential Conservation – *How can SAHRA’s Residential Conservation House teach us ways to conserve water in our homes?*

**A. Objective:** Students will apply the understanding that as they become more aware of how they use water they can think about using it more wisely.

**B. Lesson Overview:**
This lesson is designed to get students to apply what they learned by doing their homework assignment. SAHRA’s Residential Conservation web page will be the main resource in which students will learn about ways water is used around the house, both inside and outside. They will examine ways to practice water conservation. As developed below, the lesson will have students work in small groups and learn about a specific area. This information will then be shared in a teacher-led discussion. This lesson should last approximately 50 minutes and can be easily altered and adapted as the teacher desires.

**C. Materials / Resources Needed:**
- SAHRA Residential Web Page at: [http://www.sahra.arizona.edu/programs/water_cons/home/home2.htm](http://www.sahra.arizona.edu/programs/water_cons/home/home2.htm)
- Student copies of the Fact-Finding Chart

**D. Instructions**
1. Instruct students to get out their home water survey that they did as homework.
2. Ask them if they found anything to be surprising or especially interesting.
3. Ask students if they know how much water on average it takes to brush one’s teeth, shower or bathe, flush the toilet, wash dishes in a dishwasher, or do laundry. [Answers: brushing teeth, 2 to 5 gallons; bathing, 9 to 12 gallons; flush the toilet, 4 to 7 gallons; dish washing, 8 to 13 gallons, laundry, 35 to 50 gallons of water.]
4. Ask them what they learned about doing their homework last night.
5. Tell them that today they will work in small groups and examine the SAHRA “conservation house.” [The teacher has the option of displaying this website: ([http://www.sahra.arizona.edu/programs/water_cons/home/home2.htm](http://www.sahra.arizona.edu/programs/water_cons/home/home2.htm)) on a large screen from their computer, to make a transparency of the site, or to make copies and distribute them for the students to use.]
6. The areas of the home that will be studied are: Kitchen, Bathroom, Utility Areas, and Outdoor Functions.
7. Tell them to move into groups of 3 or 4 and to designate a captain. Give each group a Fact-Finding Chart.
8. Each group will be assigned one area of the house to investigate water use and ways to think about conserving water use. They will record their results on the sheet provided and report back to the class after about 25 minutes of fact-finding and analysis.
9. Assist students as needed and when the time has expired reassemble for a classroom discussion where students share the information they learned with the rest of the class.
10. Conclude this lesson by asking students to write 3 facts that they have learned that they aspire to use and apply at home.

E. Materials
### Fact-Finding Chart For Student Fact-Finding Activity: SAHRA’s Residential Conservation House Website

<table>
<thead>
<tr>
<th>HOME AREA / WATER DEVICE</th>
<th>IMPORTANT FACTS ABOUT WATER USE</th>
<th>POTENTIAL FOR WASTING WATER</th>
<th>WAYS TO USE WATER MORE WISELY</th>
</tr>
</thead>
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</tbody>
</table>
F. Additional Resources

Ways to check out toilet for leaking and consequent repairs

Homeowners guide to using water wisely (pdf)
http://www.cityoftucson.org/water/conservation/homeowner/homeowner.htm

Tucson Water
www.cityoftucson.org/water/

Simple techniques for efficient landscape watering

Water harvesting

G. Extensions

Have students form small groups and ask them to design a colorful poster that would impact homeowners to adopt more efficient water usage practices (in-home, landscaping, harvesting). Each poster should incorporate a minimum of five water concepts related to conservation. It would be best to have students do their brainstorming and initial designs on regular 8.5” x 11.0” paper. If the interest is at a high level, then students could do their posters in a more professional manner on 18” x 24” paper and possibly post them around the school grounds. For extra credit, the students might arrange to display the posters at local hardware, home center, and plumbing stores.
Inquiry 3: Lifestyles - How have different culture groups used water resources in the Southwest to meet their needs?

A. Objective: Students will understand that all culture groups living in the Southwest have made lifestyle choices based on how they acquired and used the relatively scarce water resources in this region.

B. Lesson Overview:
This lesson is designed to help students learn about how different societies have historically used the water resources in the Southwest. The lesson format offers a learning opportunity based on a classroom lecture/discussion. The lesson below provides a case study that focuses on southern Arizona. Students will come to appreciate to what extent our present society tends to overuse these limited resources, which will also help them extend the context of the inquiries they have made thus far. This lesson should last approximately 50 minutes can be easily altered and adapted as the teacher desires.

C. Materials / Resources Needed:
- Maps (currently under development)

D. INSTRUCTIONS
1. First show a very general outline map of Arizona and New Mexico to be followed by overlays described as a
   a. General population pattern from circa 1000 CE. Ask students to observe the patterns they see and suggest a hypothesis to explain them.
   b. Remove that overlay and replace with a pattern showing the metro areas of Phoenix, Tucson, Albuquerque-Santa Fe, Las Cruces-El Paso. Ask students if this information reinforces their hypothesis.
   c. Remove that overlay and replace with one that shows the general outline map that now has lines indicating the major rivers (unlabeled). Ask students if they can interpret what these lines mean and how it may relate to their working hypothesis.
   d. By now they should be able to convert the hypothesis into a thesis because they have supporting evidence that can be expanded and reinforced with other data showing that water has played a central role in deciding where people have decided to live.
   e. Next show them a basic topographical map of southern Arizona; this map has the names of major mountain ranges and river systems (Santa Cruz, Gila, and San Pedro). Tell students that rivers are among the forces that shape the landscape. In humid areas rivers are deep and they often serve as natural arteries of travel. River valleys in both humid and dry areas also become easier places to facilitate travel and were often first used by wildlife. They also became places where people moved along and in chosen spots formed communities. These were carefully chosen so that water was readily available at a point that connected other routes of travel to other communities. For example, in 1540 Coronado entered Arizona from Mexico following the route of the San Pedro River passing near where, for example, Tombstone was later established. Big trees drinking into the shallow water table
along rivers provided welcome shade for thirsty, tired travelers to escape the merciless sun.

f. After that is explained, tell them that the Hohokam lived in the Santa Cruz valley (also even more extensively in the Salt and Verde Valleys in the Phoenix metro area) and established many farming communities. Explain that these people manipulated water resources via ditches and diverted streams in order to raise crops.

g. By the late 18th century when the Spanish were establishing missions as they extended north into Arizona from Mexico, there were many American Indian settlements located along the Santa Cruz and San Pedro Rivers. Indian communities had existed near and along these rivers for centuries.

h. Tucson was selected as a presidio by the Spanish in 1775 to replace Tubac, which had been established 23 years earlier. Both were along routes that the Apaches used to raid southern Arizona and Sonora. The Tohono O’Odham villages lay along this pathway and the presidios were built to protect the missions and the Indian people whom the Spanish were wanting to protect. The mission San Agustin was located in the present Rio Nuevo area just west of downtown because the Indians already had a community there. This was also close to the spring that emerged from the base of A Mountain and flowed into the Santa Cruz, the meaning in the language of the Tohono O'Odham of the name Tucson.

i. Tucson remained the largest community in Arizona until the 1920 census was taken when Phoenix surpassed it. The primary reason why Phoenix would mushroom in size after 1910 was the vast amount of water delivered from Roosevelt Dam, the first major reclamation project begun under the 1902 National Reclamation Act.

j. The total population in Arizona Territory until late in the 19th century was smaller than it had been during the Hohokam-Anasazi period, which peaked around 1200 CE. It should be noted that these pre-historic Indians depended exclusively upon surface water, unlike modern inhabitants who also make considerable use of groundwater. As Southwestern settlers’ demands for water increased towards 1900, groundwater was mined in greater amounts. As this happened the flow of the Santa Cruz River through the Tucson Basin became more erratic, accentuating the natural wet and dry cycle.

k. Late in the 19th century visitors described Tucson as a hot, dry, dusty complex of mud (adobe) huts. The primary reason residents could tolerate life in Tucson was because surface water was nearby. We can get a glimpse of this nearly forgotten past by reading Tom Sheridan’s account of Carrillo’s Gardens, established by Don Estevan Carrillo, a leading businessman of Tucson during the latter 19th century:

During the mid 1880s, he decided to combine his love of gardening with his keen appreciation of profit by opening a resort for the people of Tucson. The result was Carrillo’s Gardens—eight acres of rose gardens, fruit trees, and man-made lakes.... Fed by local springs, the Gardens were an oasis of natural beauty in the desert.... There Tucson’s most prominent citizens held their formal parties, dancing under the stars to Carrillo’s orchestra. The general public also flocked to the resort, picnicking, boating, and listening to music on Saturday nights and Sunday afternoons. (Thomas E. Sheridan. Los Tucsonenses: The Mexican Community in Tucson, 1854-1941. Tucson: University of Arizona Press, 1986, p. 51)
Today the lakes are long gone, and apart from subsequent construction, the landscape appears parched with no hint that this could have happened.

1. By the late 19th century the Anglo-American development of southern Arizona emphasized mining and agriculture, both using significant amounts of water. Of these two powerful economic engines of change, agriculture used vaster amounts of water. The fields that dated back to before the arrival of the Spanish that were modestly extended by Hispanic farmers and later by early settlers were dwarfed in size and scope as agriculture expanded through the Tucson Basin, relying on irrigation systems using surface and mined water.

m. Agriculture remains the largest user of water although its proportion is declining. Of all the water used in 1963, 93% was used by agriculture, 5% for municipal purposes, and 2% for industry and mining. By 1995, those numbers had changed to 81% agriculture, 14% municipal, 4% industry and mining, and 1% for electric power generation.

n. Since agriculture was a vital part of the lifestyle of Arizonans into at least the early 20th century, its replacement with urban employment has brought forward the issue of job creation. Various Chambers of Commerce have received broad endorsement for campaigns to attract "clean industry" to Arizona. High tech industries have been perceived as the ideal choice. However, what is not commonly known is that these industries use large amounts of water and contaminate a significant portion of the water they use. More EPA toxic Superfund sites are found in California's high tech Silicon Valley than in any area of similar size in the US. It is estimated that up to 30% of Phoenix's underground water is contaminated, much more than half of it by high tech industries.

o. Quite obviously, then, as the predominant lifestyle of the Southwest has become heavily urbanized, water quantity has become more tightly linked to water quality.

p. This brief survey of southern Arizona lifestyles indicates how water played a central role in development patterns and how the cultural choices made by each group have affected southern Arizona's water resources.

2. Questions for discussion (according to the format decided by the teacher as explained in the overview above):

a. How is the history of the Southwest viewed differently from this perspective that places water in the center of the story? [History is normally person-centered, and thus the stories told may describe a landscape but often only to the extent that descriptions are given about key developments including building homes, establishing an economic basis and conflict, particularly those involving Indian resistance. When water is placed front and center, we see better why communities were established and how lifestyles were built around how best to utilize and manipulate available resources, especially water. We can also get a sense that the Tucson Basin had more perennial surface water before the demands of settlement activities and development diminished surface water flow.]

b. How difficult would life have been in Tucson before evaporative coolers and air conditioning, and how might Carrillo’s Gardens have offered refreshing relief from a hot, rather dry climate? [It would be hard to imagine oppressive heat without relief except in the shade. Like sitting near the swimming pool and being able to cool off by wading in or swimming in the water, the lakes in the gardens offered that possibility. In addition, the appearance of fruit trees and other comparatively lush vegetation offered a pleasant break from the glaring desert landscape.]
c. In the information provided in this lesson we learned that mining groundwater in increasing amounts adversely affected surface flows, which in time eliminated the possibility of sustaining Carrillo’s Gardens. Agriculture was the major cause of this, but its proportionate use is declining. Why, then, are groundwater tables still tending to drop lower? [Increased municipal use reflects growth of metropolitan areas of southern Arizona, Phoenix and Tucson.]

d. Write a summary of specific understandings learned from this lesson that connect to the previous inquires. [Students should be able to see that their lifestyle choices match quite well with the demographic shift to urbanization since around 1880. The societies that have been the heaviest users of water resources, the Hohokam and current residents, have that urban connection. While the Hohokam did not develop large cities, they did establish a kind of metropolitan community structure built around their numerous interlinked farming villages.]

E. Extensions

1. This activity would be most applicable for teachers in southern Arizona
2. The city of Tucson has moved ahead with a plan to revitalize the historic district
   a. This project has been called Rio Nuevo, a vision to connect Tucson’s past and present towards a more meaningful future.
   b. As a result extension archaeological work continues to be done with exciting results that is rewriting the history not only of early Tucson but of the entire Southwest.
3. The teacher is offered two suggested options that may be done separately or combined.
   a. In cooperation with the Arizona Historical Society, an excellent set of lesson plans tied to Arizona state academic standard is available free of charge to teachers called *Downtown Under Ground*.
   b. The Arizona Historical Society has designed a wonderful visual look at the history of the Santa Cruz River and offers guided tours for students. For more information contact: Kyle McKoy, Arizona Historical Society, 949 East Second Street Tucson, AZ 85719, (520) 628-5774 ext. 188, kylev@vms.arizona.edu
Inquiry 4: Constructed Water Systems - How is our society able to deliver water to where people in the Southwest want to live?

A. Objectives:
1. Students will be able to explain how constructed water systems redistribute and deliver water to supply the needs of various users, especially growing urban populations.
2. Students will understand constructed water systems such as CAP, canals, aqueducts, water mining and reservoir storage and how they apply to modern urbanized life.

B. Lesson Overview:
This lesson is designed to help students learn about how our modern lifestyle in the Southwest has been sustained by large-scale water delivery systems. The lesson format offers a learning opportunity based on a classroom lecture/discussion. The lesson below directs student learning through two basic concepts, urbanization and constructed water systems. Students will come to appreciate that these systems have required a huge capital investment with a level of technology that has extended our dependence on mined groundwater as previous inquiries have indicated. This inquiry should last approximately 50 minutes and can be altered and adapted as the teacher desires. A CAP PowerPoint is under development to accompany this lesson.

C. Materials / Resources Needed:
Teacher: Transparencies or photocopies of guided question, term/concepts and, the questions to be answered by doing this inquiry.
Student: Research Log, One or two sheets of writing paper.

D. Instructions
This plan is designed for one class period. The teacher will have to decide, based on the knowledge level of the students, length of the class period, etc. how to adapt this plan. In addition, it is left to the teacher’s discretion as to how much of a written product they want from their students in the evaluation process.
1. Have written or typed this guiding inquiry question on your chosen media: How is it possible for more and more people to move to the Southwest where water resources are scarce? Have students then respond to what they think this question means and how it may apply to them. [The key point is that with little visible natural surface water, populations have risen dramatically in the Southwest. The Phoenix metro area has over 3 million people, Tucson’s population approaches 1 million and Albuquerque’s is over 600,000. Even so, people keep coming and water seems to be readily available.]
2. Have written or typed the following term-concepts to be learned and applied:
   a. Urbanization:
   b. Aqueducts:
   c. Reservoirs:
   d. Mine:
3. Ask the students to define orally what they think each of these terms means.
   a. Urbanization: The growth of cities
   b. Aqueducts: Surface waterways or canals that move water by gravity flow
   c. Reservoirs: Man-made storage areas to retain water for future use
d. Mine: *To extract from beneath the earth’s surface*

4. Instruct students that they will work in small groups after you have explained what they are to do. This activity will allow students to apply understandings about the water supply system in their area and the impact of construction.
   a. The desired work group size is 3 to 4 students.
   b. Have each group select a captain.
   c. Instruct students that they need to complete this task in 20 minutes in preparation for a classroom discussion.
   d. Then begin to explain the task. Instruct students to identify the primary means by which water is brought into their school using the appropriate term-concept above. [This will, of course, vary. Many delivery systems will come from a local water company with some or all of the water coming from groundwater. Some schools will have their own wells and thus rely entirely on groundwater.]
   e. Instruct them next to estimate the surface area in square feet directly affected by construction in the building that their classroom is housed. [Since students probably will not have a good way to estimate size, you may want to provide them with the dimensions.] Instruct them to calculate the areas in square feet for each of the following: roof of the entire classroom building; attached coverings (e.g. awnings, etc.) if any; adjacent sidewalks; any other concrete or asphalt surface in the immediate area. If any guttering is used note where that water is collected.
   f. Next students will need to estimate the volume of water in gallons that will run off if one inch of rain fell over this area. (1 cubic foot of water = 7.48 gallons.)
   g. Ask students to discuss and then write an answer to this question: *Besides providing a barrier to the natural surface area and thus preventing at least some percolation to occur, how does this construction affect the natural process of water flow?* [Not only will the quantity of water moving to a local wash increase but also its flow rate, which increases the potential for flash flooding.]
   h. Ask students to apply their estimates to the entire campus. [You will want to give them these estimates and decide how involved you want this to be.]
   i. Add one more piece, landscaping. Have them consider to what extent the campus landscape is sensitive to water scarcity?
   j. Return to the large group (classroom) and spend about 5 minutes having students discuss their results, particularly their deeper understandings. [Students should begin to have a clearer idea about how construction built to accommodate relatively dense populations has a definite impact by reducing natural groundwater recharge and increasing the threat of localized flooding.]
   k. Thus far students have focused on this aspect of urbanization on a micro-level. Now expand the inquiry towards a macro view. While this will vary according to the community in which the students live and can become very complex, it is important for students to appreciate that housing developments, shopping malls, roadways, bike lanes and other kinds of development have a huge impact on water recharge and flow. In addition, as urban density increases, surface water resources become insufficient and a growing reliance on mining groundwater results. This is especially true in the Southwest since natural surface water supplies are much more limited than in humid regions. Your lecture/discussion should the ways in which water is transported to developed areas and ask students to explore how this relates to their lifestyle. Have students consider the relationship between urbanization and recharge. The negative impact of urbanization on recharge and the increasing tendency to mine water could threaten a sustainable water supply in the future. [The lecture/discussion has focused on water quantities without consideration to water quality issues, which would greatly
expand the inquiry at this point. The teacher may want to just tell the students a few simple facts about water quality relative to what they have already learned: The amount of impurities in surface water increases with time held in reserve or distance from the consumer. As more water is mined water tables fall, which reduces the quality of that water. Urbanization in the Southwest tends to increase the cost of water because increasing amounts of water in the system require treatment to enhance purity.]

l. Closure: Have students to write a paragraph for each of the following questions: 1] How does urbanization affect how modern water systems redistribute and deliver water in order to supply the needs of various users, especially growing urban populations? 2] How do modern water delivery systems accommodate rapid urbanization in the Southwest? 3] What impact could this process have on future water supplies?

5. As a closing activity show the titles of the first four inquiries on your chosen media (Personal Water Use Diary, Practicing Residential Conservation, Southwest Lifestyles, Modern Water Delivery Systems). Have the students look over their Research Logs for 10 minutes to reflect on the first four inquiries. Students would then be given 15 minutes to write a brief reflection on their growing understanding of the relationships among these first four inquiries.
Inquiry 5: Southwest Water Cycle Diagram - How does the Southwest Water Cycle establish the parameters of life in this region?

A. Objective: Students will explain the basics of the Southwest Water Cycle and how larger human populations are affecting it.

B. Lesson Overview:
Students will learn how humans interact and affect the regional water cycle. The lesson format offers a learning opportunity based on both small and large (classroom) discussion. This inquiry should last for TWO PERIODS, approximately 50 minutes each and can be altered and adapted as the teacher desires.

C. Materials / Resources Needed:
- CD or cassette tape of water sounds and CD or cassette tape player
- Markers
- Masking tape
- Large pieces of paper (poster size).

D. Instructions
This lesson is unique within SPLASH in that it provides a teacher script paralleled with instructions for teacher actions. It is structured using the 5E model of inquiry (Bybee, 1997).

1. ENGAGE: Focusing students on lesson topic.
   - Close your eyes.
   - You are a drop of water.
   - Picture in your mind the path you take on a journey through the biosphere.
   - Where do you start?
   - Where are you going?
   - Where do you stay for a while?
   - How long and in what form?

   **Teacher actions**
   As teacher begins guided imagery, lights should be dimmed and media with water sounds should be played. A common technique is to start with a normal speaking voice and reduce voice volume and slow talking speed as the questions are reached. This step should take only a minute or two. Bring students back slowly. Slowly increase light brightness as well as voice volume.

2. EXPLORE: Determining students’ prior knowledge.
   - Now, while the journey of the drop of water is in your mind, draw a diagram of the water drop’s journey through the natural landscape.
   - Briefly write descriptions of what happens at each major step of the diagram.
   - Now, on the big piece of paper, draw a

   **Teacher actions**
   This step is a reflective activity used to organize student prior knowledge. This is an individual task. Allow students no more than 5 minutes to draw their diagrams.

   **Teacher actions**
   This is a group task that should last no more than 5 to 10 minutes. Group members must
**3. EXPLAIN:** Introducing content (vocabulary, concepts)

- **Teacher script**
  - Take a few minutes to look over the diagrams.
  - How are they similar, and how are they different?
  - In your groups, choose three similarities and differences between the diagrams.
  - What is similar and different between the diagrams? (Write responses on the board. Use T-chart)

If students note descriptions, then add vocabulary, e.g., “I see that the presence of rain was noted by everyone. Can water fall from the sky in any different forms? Water falling from the sky is called precipitation by scientists.” (The teacher can adapt this according to the flow in the classroom at this point such as implementing the vocabulary portion described immediately below this table.)

If students note vocabulary terms or specific concepts, probe for understanding, e.g., I noticed that this diagram here has the word “evaporation” where others do not. What do you mean by evaporation?

- **Teacher actions**
  - This is a very important step, because here is where new content is introduced. However, it is introduced after students have experiences or reflect on their own prior knowledge and experiences. This ensures that students have some prior experience to relate to vocabulary and concepts.*
  - This step can also be long as meaning is to be probed for clarity.

As similarities and differences are being discussed, a class summary water cycle should be constructed concurrently with the class discussion. This will provide a more complete picture of the water cycle based on all student input.

**4. EXTEND:** The following activities are designed to apply knowledge and increase student understanding of the water cycle. It is recommended that students be divided into groups of 3 to 4. One activity should be assigned per group. The students will present their results for their classmates on the following day. It is recommended that the teacher collect the data sheets at the end of class so that they are available on the next day.

**Student Instructions**

- **Activity 1** – What is the relationship between the water cycle and water supply? How else is water supply affected? Construct a model of water supply and demand and determine how the water cycle is related to water supply.

- **Activity 2** – Which components of the generic water cycle would be emphasized over others as seasons changed? Manipulate components of the water cycle to reflect what happens at different times of the year.

- **Activity 3** – Does the generic water cycle reflect the desert southwest? If not, where does the water cycle every learned come from? If the water cycle is to model the desert southwest, what would it be modified? How would it be different from the generic model? What about seasons?
Activity 4 – Go outside and locate human constructions that may influence components of the water cycle. Write brief descriptions of their dimensions and the materials that were used to make them (OR, take pictures of these constructions) and describe how they impact specific components and the water cycle as a whole.

Activity 5 – Design experiments to determine the impact of human constructions on water cycle components.

Activity 6 – Using historical climate data, determine if there have been any changes in climate and the water cycle from the past to the present. Speculate on the influence of human constructions on these changes.

**EXTENSION continued / DAY TWO: Student Knowledge Sharing**

<table>
<thead>
<tr>
<th>Teacher Script</th>
<th>Teacher Activity</th>
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<tr>
<td>(The presentation order should be according the Activity number. In the event that more than one group has done the same activity, have one be the primary presenter and the other asked to offer any differing perspective or point of information.) Each of the students that have done the other activities are to record their response to the information. You may ask questions for clarification.</td>
<td>Assemble the class in such a way that each presenting group can be clearly seen. Ask a question when appropriate or make a comment that will help to clarify what each student needs to understand about each activity. As a result of doing these activities and collecting the information from them today, students will build a fundamental understanding of the water cycle and how our interactions with it affect the quantity of our water resources. (You might tell students that this inquiry concerns the quantitative aspects of the water cycle. The quality of water interacting within this cycle would also have to be done in order to understand the water cycle more holistically.)</td>
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**Anticipated Understandings**

**Activity 1** - The student model should reflect the concept of supply and demand. This might be represented graphically to show what happens to a given supply of water as human demand increases. Students should understand that as more people choose to live in the Southwest the demands on our water resources increase. Other plant and animal groups find it harder to compete for these essential sources of life.

**Activity 2** - The student model could break down parts of the water cycle as it applies to the known seasons of the Southwest. Students should understand that seasons affect the water cycle. During the heat of the day evapotranspiration increases. Monsoonal and winter rainy patterns tend to increase potential supply. Too much rain increases the flow and reduces the potential for recharge.

**Activity 3** - Students should be able to draw a model that is more representative of the specific area of the Southwest in which they live. The standard model works in general but particular elements are different for the Southwest.

**Activity 4** - Students most likely will have observed the campus. Some parts of campus (or the off-campus buildings nearby) are more heavily constructed than other. Their data should indicate the type (e.g., buildings or concrete pavement) and have some estimate of scale. Student data collection should recognize how human construction impedes direct contact between earth and sky and thus, depending on scale, negatively impacts the water cycle.
### Activity 5
Students should be able to show in some graphic way how buildings prevent precipitation from landing on the ground underneath, and how roofs, sidewalks, etc. increase the rate of flow, thus largely denied entry into the aquifer.

### Activity 6
Using weather service records it should be very easy to show the effect of urbanization on temperatures. They should understand conceptually that this affects evaporation both from the surrounding landscape and from the bodies of people, animals and plants (transpiration). Students should be able to explain that human construction tends to raise temperatures, which in turn increases the rate of evaporation. In addition, hotter temperatures require people to use more water.

### 5. EXPANSION: Making Connections

<table>
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<tr>
<th>Teacher Script</th>
<th>Teacher Actions</th>
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<tr>
<td>The water cycle functions like a kind of giant pump in which water moves from earth to sky and then returns again. The largest source of water to make rain is the oceans. The global water cycle can be understood at this point as the basic process in which water is continually recycled, creating our water resources as a result. Within the global water cycle and interacting within it are regional water cycles, such as the Southwest Water Cycle, that are influenced by regionalized and localized climate, topography and human actions.</td>
<td>Direct student attention to the water cycle and illustrate this circular pattern. Explain that this model is generic in the sense that it shows the main ingredients of the global cycle. Major wind patterns such as the trade winds, the tilting motion of the earth's axis, heating and cooling, low and high pressure systems, small storms and large, all interact to affect weather around the world and thus water cycling on a global scale and then with regional ones. As you point to the chart identify specifically the areas that show runoff.</td>
</tr>
<tr>
<td>In humid areas water may continue to flow in surface streams or lakes. Precipitation that seeps into the ground (percolation) is stored in an aquifer. The amount of precipitation, the rate of recharge, the size of the aquifer plus the direction and rate that this groundwater moves are important natural factors that determine how much groundwater exists.</td>
<td>Continue to refer students to the water cycle diagram. Point to the place that has the word percolation.</td>
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<tr>
<td>As we have seen, human demand for water can affect its supply. As population increases the demand can also affect groundwater so that if more water is consumed than nature can supply and re-supply, rivers shrink in size and may even disappear, and the water table gets lower as more water is mined.</td>
<td>Continue to refer to the water cycle diagram. Point to the aquifer and to the water table as displayed.</td>
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<tr>
<td>We have also seen that human construction can interfere with the water cycle and reduce the amount of available water.</td>
<td>As you have students look at the water cycle diagram, illustrate how roofs or concrete can eliminate percolation over the area affected and increase runoff.</td>
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<td>So far, we have examined the water cycle in a generic way. What I mean by this is that the human interaction with the water cycle can apply to almost anywhere in the world. But while we might think of planet earth having one giant water cycle, local conditions around</td>
<td>As you explain this you might use your arms and hands to demonstrate a large cycle, and then make smaller circular movements within the area that you first gestured.</td>
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the world create many water cycles within the whole. Please understand that interaction is the key concept. Local water cycles and human interaction with them also affect the global water cycle even as the global cycle interacts to affect local ones.

Here is the water cycle as it applies to the Southwest. Notice that the surface area appears dryer than our generic model. It is important to understand that in the Southwest the water cycle has less water with which to work. It is also important to understand and to appreciate that all over the earth water continues to move as it is recycled from earth to sky to earth again, in perpetual motion. We depend on it and we definitely affect it.

Show students water cycle diagram appropriate for the Southwest.

* Here are examples of SOME words and their definitions that might be included. This list is not intended to be comprehensive. It is provided here to assist the teacher and should NOT to be introduced to the students in any way other than that described above.

a. Condensation - The process by which water is transformed from a gas to a liquid.
b. Transpiration - The process by which water is transferred from plants into the air as water vapor.
c. Evaporation - The process by which water leaves a surface area as it is transformed into a gas, i.e., water vapor.
d. Virga - Any form of water that falls from clouds but fails to reach the landscape below.
e. Precipitation - Any form of water, liquid (e.g. rain) or solid (e.g. snow) that falls from clouds reaches the landscape.
f. Flow - Water generally moves towards ocean basins by force of gravity, either along the surface in rivers, and streams, or underneath the ground in the aquifer.
g. Runoff - Water that flows across the landscape without seeping into the ground, an action called percolation.
h. Recharge - The action of water seeping into the ground.
i. Groundwater - Former precipitation that collects beneath the surface and stored in an aquifer.
j. Water Table - The top of the water surface in the saturated part of the aquifer.

Assessment: Ask students to write a brief statement in response to this statement: Human interaction with the water cycle has a potentially greater negative impact on water resources in the Southwest, especially during the present era of rapid urbanization.

Inquiry 6: Personal Monsoon Experiences – How do our personal monsoon experiences connect to an understanding of water cycling in the Southwest?

A. Objective: Students will increase their interest in and understanding of the role of the monsoon in affecting the quality of life in the Southwest.

B. LESSON OVERVIEW:
This lesson is designed to help students make connections from their own personal experiences to an important part of the Southwest’s water cycle. The lesson format offers a learning opportunity based on both small and large (classroom) discussion. This inquiry should last approximately 50 minutes and can be altered and adapted as the teacher desires.

C. Materials / Resources Needed:
Transparencies or photocopies of the following:
- Major questions in the inquiry
- Inquiry chart
- Poem by Ofelia Zepeda (if available)
- Precipitation data from the NOAA for Tucson and Mount Lemmon

D. Instructions
1. Instruct students to get out a sheet of notebook paper.
2. Instruct students that you want them to focus on a monsoon thunderstorm experience that is the most vivid that they can remember.
3. Instruct them to reflect about this storm and especially the various sensations that they experienced (what they saw; how they felt; what they heard; what they could smell before, during and after.)
4. Instruct them to briefly write these down as they think of them as if they were collecting data.
5. Instruct them to create three columns on their paper as you now display on your primary media (board, overhead, etc.):

<table>
<thead>
<tr>
<th>Pre-storm</th>
<th>During storm</th>
<th>Post-storm</th>
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6. Instruct them to organize the various sensations that they wrote down and place them in one of the three columns. Instruct them that they can include other memories that this process might stimulate.
7. Instruct them to write a sentence or two in response to this question: How does the summer monsoon period affect how I feel about living in the Southwest?
8. Ask several students to share their answers as they summarize their most vivid monsoon storm experience.
9. After you have given them time to share (up to about 10 minutes) provide the following information:
The rainy season, which usually begins by mid-July, is characterized by powerful but localized afternoon thunderstorms, which often develop with amazing speed. A rapid greening follows the rains, and many birds, including Botteri's Sparrow, Violet-crowned Hummingbird and Eared Trogon, delay nesting or nest a second time to take advantage of this short-term bounty. Mexican bird species often fly into southern Arizona, cruising along on the moist, tropical winds, while birds from the northern US and Canada (such as Lazuli Bunting, Yellow-headed Blackbird, American Avocet, and Baird's Sandpiper) migrate to this temporary paradise. Since the rains produce a bounty of wildflowers, this "second spring" is also the time of greatest diversity and abundance of hummingbirds and butterflies. Hummingbird diversity usually peaks between late July and mid-August, while the greatest variety of butterflies are visible between late August and late September. A few early migrants, including Sulphur-bellied, Cordilleran, and Buff-breasted Flycatchers, are already headed south to Tucson by early September. In most years the regular afternoon storms bring a welcome drop in temperature just as the heat is building to uncomfortable levels, and there is a jump in bird activity as soon as the storm passes.

10. Next, you may want to read them the poem Rain by Ofelia Zepeda (from When it Rains- Paqapago and Pima (Tohono O’Odham) Poetry, Ofelia Zepeda, ed., Tucson, AZ: The University of Arizona Press, 1982, p. 41)

11. Ask students to reflect about the meaning of this poem. Their responses should reinforce the consensus already built about how the summer rains change the way we feel and make life more tolerable during the long hot summer.

12. Ask students to describe in words and/or images their understanding of the atmospheric processes involved in creating the monsoon.

13. You may wish to provide the following background information to students.
   a. The Southwest has both semi-arid (receiving an average of 10-20 inches of precipitation per year), and arid (where precipitation averages below 10 inches per year) areas.
   b. Mountain areas (referred to as “sky islands”) generally average above 20 inches of precipitation per year.
   c. The Tucson Basin lies in a semi-arid climate zone with surrounding sky islands, particularly the Santa Catalinas, Rincons and Santa Ritas.
   d. These mountain ranges interact with the seasonal wind shifts that pull moisture-laden air northwestward from the Gulf of Mexico and/or the Gulf of California, forcing this air to rise, which causes cooling and a release of moisture as rain.
   e. Tucson and the Southwest experience annual and decadal climatic shifts between wet and dry.
   f. Each year typically includes two wet periods, the summer monsoon and the winter rainy season. On average, the summer monsoon supplies over 50% of the year’s total precipitation total. The winter rainy season supplies about 30%. The other two seasonal shifts to dry that total about six months out of the year supply the remaining 20%.
g. NOAA precipitation data for Tucson and Mt. Lemmon are recorded in the table above. Ask students to compare the two stations and identify the months of the two wet seasons and then to compare the totals for each station. For students living in the Tucson metro area, you can also ask them to describe what they know about the vegetation differences between the areas. (This is easily applied for other areas of the Southwest wherever this activity is being done.) Ask them if they can identify any pattern that identifies the climatic cycle of wet and dry.

14. After this discussion, ask students which of the two wet seasonal cycles are of greater benefit. Students may jump for quantity and answer the monsoon season, while others may smell a set up and say the winter season. You may have them consider what is meant by benefit. Ask them, which action will allow water to seep into the ground to a greater extent, rapid bursts of rain typical of monsoon storms, or slower, steadier rains plus snow in the mountains that falls and gradually melts? Students should be quick to see that the winter pattern is actually more beneficial for groundwater recharge. This in essence shifts the thinking from qualitative benefit to quantitative benefit.

15. Closure can be achieved in various ways. One way would be to ask students to define from memory the terms arid, semiarid and sky island. In addition, you can ask them to write an essential factual understanding that they learned during this inquiry.

E. Additional Resources:

Thunderstorm safety
http://phoenix.about.com/library/uc062101b.htm?iam=sherlock_abc

Road weather information
www.azfms.com

NOAA
www.wrh.noaa.gov

Tips for birding travelers
http://www.sabo.org/birding/tips.htm#rain
Inquiry 7: North American Monsoon - How does the North American monsoon affect water resources?

A. Objective: Students will be able to explain how the North American monsoon contributes to both the quality and abundance of life in the Southwest.

B. Lesson Overview:
This inquiry will have students apply what they learned about their personal monsoon experiences to how the monsoon forms within the global seasonal pattern and interacts with local factors. In addition they will learn about the complexities of this seasonal weather pattern and how it provides both benefits and liabilities to life in the Southwest region. The lesson format is primarily lecture/discussion. This inquiry should last approximately 50 minutes and can be altered and adapted as the teacher desires. Additional options are offered to expand the inquiry to a second day if desired.

C. Materials / Resources Needed:
- Display of related Web sites, if possible

D. Instructions
1. Check student understanding of the concepts of wet and dry as they apply to climatic and seasonal patterns. The essential understanding is that shifts between wet and dry occur on a large scale (climatic) that last for years even decades, and on a yearly or season scale, or over several months. The monsoon is one of two wet seasonal cycles in the Southwest, the wetter portion of the two.
2. Review the topographical dynamics of the Southwest, particularly the role of mountains (sky islands) that force air to rise, which creates cooling, vaporization (evidenced by clouds) and, if enough moisture is present, precipitation, which falls over the mountains and may also reach valley floors. You may want to have a transparency showing your local topographical features.
3. It is important that students appreciate the interaction of the regional topography and the seasonal shift that brings in moist, tropical air from the south.
4. Introduce more specific information about the North American Monsoon.
   a. A key part of the water cycle is evaporation a process that allows an exchange of moisture from ground level to the atmosphere.
   b. An axiom of weather science (meteorology) is that warm air holds more moisture than cold air. This is important to know because it is critical to the North American monsoon since the source of the summer rains is the moist air rising above the warm, tropical waters of the Gulf Mexico and the Gulf of California.
   c. Normally during mid-summer the global pattern, in response to the long daylight hours in the northern hemisphere, creates upper air wind patterns that cause a significant change in wind patterns that flow over the Southwest. The change in direction from west/southwest (which brings dry air into the region) that heats up in May and June is gradually but significantly changed to winds that come from the southeast. This shift to warm moist winds generally becomes evident by early July.
   d. Since these winds begin over the Gulf of Mexico and/or the Gulf of California, the monsoon is strongest in Mexico and becomes progressively weaker as these forces...
move into the Southwest. Nevertheless, it is significant not only because strong, even violent weather erupts, but much of the region can receive large amounts of rainfall.


f. In June a subtropical ridge at 18,000 feet above sea level is located over northwest Mexico. As a result, the flow across Arizona is usually from the southwest. The hot and dry weather conditions experienced across Arizona during the month of June are a direct result of the position of this subtropical ridge and dry southwest flow.

g. The National Weather Service defines the presence of the monsoon when the recorded dew point averages above 54 degrees Fahrenheit for three consecutive days. Dew points just a few weeks earlier in mid-June are often lower than 10 degrees. Dew point is defined as the temperature at which the air is saturated causing condensation to occur.

h. The term “convection” is often used interchangeably with thunderstorm and is defined as the transfer of heat and moisture through the movement of a fluid. As applied to the science of meteorology this refers to the updrafts—lifting of air caused by the heating of the earth’s surface by sunlight, which causes evaporation to occur and the release of that moist air as “downdrafts” when the air becomes saturated (the dew point is reached) and thus unstable. This instability and the energy released during condensation create the power of storms.

i. In the Southwest, unless some upper air disturbance (low pressure) acts to trigger storms, it is the combination of sun heating and a moist atmosphere down to ground level that creates storm potential.

j. Sometime beginning in late August as the global shift toward autumn in the northern hemisphere becomes more pronounced this pattern gradually breaks down and the mid–level high over Texas migrates away bringing a shift to drier western winds.

k. This change is often erratic and can begin earlier or later than the average, but in the end it brings an end to the monsoon as nature begins to set up a more winter-like pattern that in the Southwest brings the secondary rainy season in late November or earlier December.

5. After checking for student understanding and responding to their questions about the dynamics of the North American monsoon, begin to share with them some basic information on thunderstorms.

a. The wind grows stronger in advance of an approaching storm. Descending, cold air creates plow winds and can swirl dust creating dust devils.

b. The winds may diminish as rain begins to fall and the ground may receive a heavy burst of rain. Some of the more energetic storms can produce huge downpours at a rate in excess of 4 inches per hour. Fortunately, not many storms are that powerful because serious flash flooding can result, especially as water rushes downward from the higher terrain. Also, it is fortunate in the Southwest that tornadoes are rare. At this point, you may want to let students “relive” an exciting storm event. This may easily lead into a discussion about lightning. Lightning represents intense energy, its flash heats the air for a brief moment to around 54,000 degrees Fahrenheit, many times hotter than the sun’s surface. You may also want to talk a little about storm safety.

c. Some of the student discussion may have been about how some storms seem to disappear as suddenly as they form or that sometimes the monsoon seems to take a vacation for several days. Even a subtle shift in upper air winds or too much hot, dry
air aloft can depress thunderstorms. The monsoonal pattern sets up the potential for rain, but many other ingredients are necessary for significant rain to occur.

6. **Closure**: Review the main points about how the North American Monsoon forms and how local conditions can interact with it, especially how these complexities make the monsoon a difficult climatic event to forecast in any detail, or even weather forecasting from day to day.

### E. Additional Resources

- **Go To:**
  [http://geography.asu.edu/aztc/monsoon.html#basics](http://geography.asu.edu/aztc/monsoon.html#basics)
  This site includes helpful illustrations and includes such topics as desert meteorology and comparisons between the Arizona Monsoon and the Asian or Indian Monsoon.

- **Go To:**
  This site gives basic information about the monsoon such as the relationship of the dew point to the start of the monsoon season storm safety.

- **Go To:**
  This site has a series of 5 satellite images from May to September that clearly shows the representative conditions as the monsoon makes its way into and out of Arizona. A quick assessment would be to make an overhead transparency of the 5 images and cut the images apart. Place the images in a jumbled order on the overhead projector. Call on students to arrange the images in the correct order and to give a brief description of what is occurring.

- **Go To:**
  [http://www.sabinocanyon.arizona.edu/index_full.html](http://www.sabinocanyon.arizona.edu/index_full.html)
  This site has FLASH and HTML animations. Click on the appropriate button depending on your Internet connection speed. Students should then go to “Flash Flooding in Sabino Creek” to understand one component related to our Southwest Water Cycle. Have the students orally summarize what they learned while visiting this site. Discussion might ensue about past experiences, etc.
Inquiry 8: The Global Water Cycle - What are the essential features that help explain how the global water cycle functions?

A. Objective: Students will explain the basics of the global water cycle and how it impacts the southwest.

B. Lesson Overview:
This lesson stresses the importance of evaporation, precipitation, and convection in the global water cycle, building a foundation for understanding global patterns. Students will learn how evaporation, precipitation, and convection are the driving forces in the global water cycle. The lesson format offers a learning opportunity based on experiment & observation, direct class instruction, as well as Internet investigations. This inquiry should last for TWO PERIODS, approximately 50 minutes each and can be altered and adapted as the teacher desires.

C. Materials / Resources Needed:
- Transparencies or photocopies of the paragraph statements in step 2 below.
- Research Log.

D. Instructions

1. Convection Experiments:
   a. Start Inquiry 8 with the first three experiments listed below so that students can “see” convection, evaporation, and precipitation. Stress that convection is the process driving our weather. For the liquid convection experiments it would be best to tell the students to think of the liquids as “thick” air so they don’t lose sight of the weather connection.
   b. You may want to form groups and have different groups do different experiments. The groups would then report back to the whole class as to what their experiments involved and what the results were. Groups could diagram or take photos of their results to share in their reports.
   c. The students will record a brief description of the experiment, the results of the experiment, and a short statement of how the experiment relates to their understanding of weather in their Research Logs.
   d. Experiments 4 through 10 are meant as extensions and are not required for Inquiry 8.

  • Go To Experiment 1:
    http://www.ucar.edu/40th/webweather/tstorms/tstorms.htm Make Convection Currents. This activity involves using a plastic shoebox-sized container, ice cubes with blue food coloring and red food coloring, calls for drawing seen patterns using blue and red colored pencils, and includes photos of students doing experiments.

  • Go To Experiment 2:
    http://www.sargentwelch.com/ec/products/index.cfm?categoryID=19067 Convection Kit. The kit has two chimneys in a transparent box to demonstrate convection with smoke. The cost is about $50. This is an optional but highly recommended experiment. It is considered optional because of the special equipment needed. SPLASH has one kit available to borrow. Notes on using the gas convection apparatus:
• **Cautions**: Candle should be put directly under one of the chimneys. Acrylic lamp chimney may melt if exposed to prolonged or excessive heat.

• The convection of a gas apparatus consists of a metal box with a glass front, two lamp chimneys, and a candle. A lighted candle provides a difference in temperature causing the air to circulate down one chimney, horizontally through the box, then up the other chimney.

• Light the candle. Since the candle warms the air, the air becomes lighter and moves up the chimney. Air moves down the other chimney to replace the air that has been removed. This circulation of air caused by unequal heating is a convection current. The heat energy must be applied at the bottom in order for the convection current to form.

• Air is invisible so it will be necessary to introduce smoke to the system to make the air motion visible. An easy way to obtain smoke is to use a 3” X 6” piece of touch paper. Roll this into a small tube. Pinch one end and light the other end and allow the paper to continue to smolder. Hold over cold air chimney. This will produce enough smoke to operate the convection box for several minutes. The green smoke sticks may be used in place of the touch paper.

• **Go To Experiment 3**: [http://www.ucar.edu/40th/webweather/tstorms/tstorms.htm#rain](http://www.ucar.edu/40th/webweather/tstorms/tstorms.htm#rain) Make It Rain. This activity involves using a jar of hot water and a plate with ice cubes to create condensation. The website does not show this, but you could use warm tap water, hot tap water, and burner heated water to demonstrate the varying degrees of evaporation, condensation, and precipitation. The rates of each will be clearly visible. As a result of this, students may be led into topic of global warming and how it relates to this experiment.

• **Go To Experiment 4**: [http://www.synapse9.com/airbox.htm](http://www.synapse9.com/airbox.htm) Convection in a Box. This activity uses smoke from an incense stick to show convection. It discusses “heavy hot air” contradictions observed in a plexiglass box experiment and other problems in demonstrating convection.

• **Go To Experiment 5**: [http://www.etl.noaa.gov/eo/pdf/Exper.html](http://www.etl.noaa.gov/eo/pdf/Exper.html) Make Your Own Convection. These two experiments have additives in fluids that are carried by fluid motion and make fluid flow easier to see. The first experiment involves cooking oil and cinnamon in a Petri dish or beaker heated on a hot plate. The second experiment involves liquid soap and food coloring heated in an aluminum pie pan on a hot plate.

• **Go To Experiment 6**: [http://members.ozemail.com.au/~macinnis/scifun/miniexp.htm#28](http://members.ozemail.com.au/~macinnis/scifun/miniexp.htm#28) Convection Snake. This activity involves cutting paper into a spiral shape and suspending it over a light bulb to demonstrate convection.

• **Go To Experiment 7**: [http://www.ucar.edu/40th/webweather/tstorms/tstorms.htm#balloon](http://www.ucar.edu/40th/webweather/tstorms/tstorms.htm#balloon) Make a Hot Air Balloon. This activity involves making a hot air balloon with tissue paper and16-gauge wire heated over a propane stove to demonstrate convection.

• **Go To Experiment 8**: [http://www.sargentwelch.com/ec/products/index.cfm?categoryID=19449](http://www.sargentwelch.com/ec/products/index.cfm?categoryID=19449) Convection Activities Kit. This kit is about $23 and has students use vials of hot water and ice to create warm and cool regions.

Go To Convection Movies: [http://groups.physics.umn.edu/demo/thermo.html](http://groups.physics.umn.edu/demo/thermo.html)  Convection Tube Movie. This site has a short movie showing convection in the rectangular shaped glass tubing available from SargentWelch. It also has other movies demonstrating convection. Movies are 5 to 8 MB.

**Experiment 10**

Students will need to be close to observe. You will probably not be able to have more than six students around a table at a time. Another method would be to have 6 to 8 students in groups conduct the experiment, with the groups reporting on their observations. **Caution students about handling the hot water.**

Use a pencil to make a small hole near the bottom of a Styrofoam cup, this is the cup you will be placing the hot water in. Use a pencil to make a small hole in about the middle of a second Styrofoam cup, this is the cup you will be placing cold water in. Add hot water that has been dyed red to the cup with the hole at the bottom, and add ice cold water that has been died blue to the other cup. Place the cups about an inch apart in the larger container (which should be full of water), with the cup holes facing each other. Watch closely for about 2 minutes. The red “plume” of hot water is very evident in a horizontal direction before mixing occurs.

Variations: Try using yellow food coloring for the hot water and blue food coloring for the cold water. It gives a different effect than the red and blue food coloring. Make the holes in both cups near the bottom of the cups to get a slightly different effect. Place the hot water in the cup with the higher hole and the cold water in the cup with the lower hole.

2. **Discussion and Connections** - Present the following to the class on your chosen media:
   a. Our weather depends on whether or not a host of variables interact and occur within a certain time frame. Many times we only think of a situation as “weather” if it involves water as rain, snow, sleet, or hail. Whether people live in “normally” dry Tucson, Arizona or “normally” wet Seattle, Washington, they tend to think of weather as involving water.
   b. As different comedy sketches put it, “There will not be a weather report for today because there was no weather today.” The meaning being that things were normal for that place and time of year.
   c. Ricky and Yolanda were all ready to go sailing on a lake near their home. They saw dark, black clouds forming to the east of the lake, and they also noticed the wind blowing out of the east. Calling the weather station, they found that a storm was rapidly advancing towards them. They decided not to go sailing and left the sailboat tied up at the dock.
   d. We tend to anticipate, sense, and look forward to changes in the weather that depend on our climate. In the desert, we anticipate the relief from the searing heat and the growth of plant life that accompanies the monsoon weather. This anticipation comes even though we know the high winds, lightning and flooding that accompany monsoon rains can be harmful.
   e. So what drives weather? Convection is the movement of energy due to density differences. As a liquid or gas is heated it expands and becomes less dense and therefore lighter. If a cooler denser material is above the hotter layer the warmer material will rise through the cooler material. The rising material will dissipate its heat energy into the surrounding environment, become more dense (cooler), and will sink to start the process over again.
   f. We can look at air behavior that affects our weather/climate generally over the globe in three zones: The doldrums, the trade winds, and the horse latitudes. Students will visit the 3 websites described below. A projection system or television hookup could be used by the teacher if individual computer stations are not available. Allow students about 15 minutes to visit and make notes for all three websites.
g. In visits to the following sites, students should include sketches in their notes for their 
Research Logs along with any written comments. The sketches will help remind the 
students of general air movements over the earth. Encourage students avoid getting 
blogged down in details, but rather formulate generalities in their notes.

**Go To:** [http://geography.about.com/library/weekly/aa050301a.htm?iam=sherlock_abc](http://geography.about.com/library/weekly/aa050301a.htm?iam=sherlock_abc)  
This site talks about the Intertropical Convergence Zone (ITCZ), also known as the Doldrums being a key component of the global water cycle.

**Go To:** [http://geography.about.com/library/weekly/aa110200a.htm](http://geography.about.com/library/weekly/aa110200a.htm)  
This website covers the role of the horse latitudes and tradewinds.

**Go To:**  
This site has an animated global precipitation map and more about the role of the ITCZ.

h. Inform students they will be visiting a website on climate. It would be best for students to 
click successively on “next” at the bottom of each page on this website while online and 
scan this site for the variety of information regarding climate. Allow maybe 2 minutes for 
students to scan the website. After scanning the pages have the students go back to the 
beginning. Have the students record notes in their Research Logs as they again go through 
the pages in more detail. Ask students to include a summary paragraph of their 
impressions of the meaning of climate at the end of their notes.

**Go To:**  
internal and external processes affecting climate. Clicking on next at the bottom of each page 
goes into global climate models (GCM) and the effects on water in terms of season, latitude, 
wetlands, etc.

i. At this point students will have a basic understanding of large scale weather patterns. If 
desired, and if time permits, a brief visit could be made to these two websites for an 
understanding of the monsoon in relation to worldwide patterns.

**Go To:**  
[http://nimbo.wrh.noaa.gov/Flagstaff/science/monsoon.htm](http://nimbo.wrh.noaa.gov/Flagstaff/science/monsoon.htm) NWS Flagstaff. This site describes the 
origins and impacts of the monsoon.

**Go To:**  
[http://nimbo.wrh.noaa.gov/Tucson/monsoon/monsoon.html](http://nimbo.wrh.noaa.gov/Tucson/monsoon/monsoon.html) NWS Tucson. This site describes the 
origins and impacts of the monsoon.
Inquiry 9: Properties of Water – *What are the unique properties of water?*

**A. Objective:** Students will increase their understanding of water properties.

**B. Lesson Overview:**
This lesson is designed to help students discover some of the unique properties of water through experiments. The lesson format offers a learning opportunity based on experiments performed in small groups. The lesson below directs student learning through basic water experiments. Students will come to appreciate the unique properties of water that shape and define our world. This inquiry should last approximately 100 minutes and can be altered and adapted as the teacher desires.

**C. Materials / Resources Needed:**
- Transparencies or photocopies of the following:
  - the quote by Jean Dorst *Water*,
  - the materials described in the four experiments below, and
  - the lab/answer sheets
- Student copies of the worksheet
- Lab equipment for each group: 3 pennies, droppers, water, ethanol, detergent, 4 beakers, salt, sugar, cooking oil, and vitamin E (liquid gel capsule).

**D. Instructions**
1. Instruct students to get out a sheet of notebook paper that they may need for additional observations that are not called for in the labs. Pass out the worksheets for the lab activities. Inform students they will be doing labs involving water properties. Assign 3 or 4 students to a group. Show the quote and four paragraphs below to the class on your chosen media, while reading aloud.

   *“Life bears the memory of its aquatic origins. Every living creature, animal or plant…even man…is above all a form of water.”* Jean Dorst *Water*, 1990.

   Water covers about 75% of the earth’s surface; it makes up from 50 to 95 percent of the mass of living organisms. It is ubiquitous. It is also one of the simplest yet most important of molecules involved in living systems. The cytoplasm of a cell is a water-based solution that contains a variety of ions, salts and other molecules that make life happen. Water is literally involved in every facet of life.

   The simplicity of the water molecule belies the complexity of its properties. Based on its small size and light weight, one can predict how it should behave, yet it remains **liquid** at a much higher temperature than expected. It also **boils** and **freezes** at unusual temperatures for a molecule of its size. Many of these unexpected properties of water are due to the fact that water molecules are attracted to each other like small magnets (cohesion). This attraction results from the structure of the water molecule and the characteristics of the atoms it contains. Each molecule of water is made up of two atoms of hydrogen covalently bonded to one atom of oxygen.
Atoms are most stable when they have a full compliment of electrons in their valance shells. Oxygen will bond with two hydrogen atoms to reach this more stable situation. However, oxygen is a strongly electronegative atom, and as such, it pulls electrons towards its protons, even when sharing them through covalent bonding with other atoms. This uneven distribution of electrons occurs in a polar covalent bond. This unequal distribution explains why hydrogen atoms in a water molecule take on a partial positive charge and the oxygen atom takes on a partial negative charge. These partial charges cause water molecules to cling to each other like magnets.

The clinging in this particular case is due to hydrogen bonding. Hydrogen bonding involves the attraction between the slightly positively charged hydrogen atoms of one water molecule and the slightly negatively charged oxygen atom of another water molecule. As no electrons are actually shared, hydrogen bonds are much weaker than covalent bonds – they easily break and easily reform again.

2. Have student complete the activities described on the student worksheet. Also inform students they may make observations not called for on the answer sheets on their notebook paper. These observations may help students formulate answers to questions for their Research Logs.

E. Materials
Properties of Water Student Worksheet

**Equipment for each group:** 3 pennies, droppers, water, ethanol, detergent, 4 beakers, salt, sugar, cooking oil, and vitamin E (liquid gel capsule).

**Part A: Drop Behavior- Water on a Penny/Ethanol on a Penny**
You will be comparing the number of drops of water and ethanol that can be placed on a penny before spilling. Before beginning, discuss and record what you think will happen in each test. Using the droppers provided, each person in your lab group is to place as many drops of water as he/she can on the head’s side of a penny. Carefully hold the dropper barely above the penny and place individual drops of water on the penny and keep track of the number of drops. Repeat this procedure three times, recording the number each time.
Sketch the water after one drop, half way and just before it overflows.

1. Prediction: How will the ethanol and water behave similarly and/or differently when dropped on a penny? _____________________________________________________________________________.

Now start with water.

**Results:**

<table>
<thead>
<tr>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>________</td>
<td>________</td>
<td>________</td>
</tr>
</tbody>
</table>

Average number of drops = __________

Average number of drops for all group members = ________

2. In the space provided, sketch the water on the penny (side view) after one drop, about half full and just before overflowing.

Water-one drop           Water-half full            Water-nearly overflowing

3. Now use ethanol, another liquid, for a comparison to water. Repeat the above procedures exactly, substituting ethanol for water.

4. Prediction: How many drops of ethanol can fit on a penny? __________

**Results:**

<table>
<thead>
<tr>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>________</td>
<td>________</td>
<td>________</td>
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</tbody>
</table>

Average number of drops = __________
Average number of drops for all group members =_________

5. In the space provided, sketch the ethanol on the penny after one drop, about half full and just before overflowing.

Ethanol-one drop                Ethanol-half full                Ethanol-nearly overflowing

6. Use the data table below to record the average number of drops of water and ethanol for each person in your lab group. Calculate and record the group average.

<table>
<thead>
<tr>
<th>Group Member Name</th>
<th>Water Average</th>
<th>Ethanol Average</th>
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<tbody>
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<table>
<thead>
<tr>
<th>Group Average</th>
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<td></td>
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</tbody>
</table>

7. A. Were there different methods used by your group members that allowed some group members to place more drops on the penny (describe)?

B. What other variables may have impacted the results?

8. Compare the results for the two liquids. Which do you think demonstrated the greatest cohesion and polarity? Explain.
**Part B: The Effects of Detergent**

1. With your finger, spread a small drop of detergent on the head side of the penny and repeat the Part A procedure with water 2 more times each. Record the results below.

   - Trial 1 with detergent =__________
   - Trial 2 with detergent =__________
   - Trial 3 with detergent =__________
   - Average number of drops=__________
   - Average number of drops for all group members =_________

2. Write a description of the effects of the liquid detergent.

**Part C: Making Solutions**

1. Fill four small beakers with 50 ml of water. You will add salt, sugar, cooking oil and vitamin E (from a liquid gel capsule) to one of each of the four beakers. Salt is an ionic compound, sugar is a polar molecular, both cooking oil and vitamin E are non-polar substances.

   Predict which substances will dissolve (go into solution) in water and briefly explain why:
   - Salt: ______________________________________________________________
   - Sugar: ______________________________________________________________
   - Cooking Oil: __________________________________________________________
   - Vitamin E: ____________________________________________________________

2. Add 10 grams of salt to beaker 1, 10 grams of sugar to beaker 2, 10 ml of oil to beaker 3, and break open one capsule of Vitamin E and add it to beaker 4.

3. **Do not stir.** View the contents from the side. Sketch each beaker and its contents below. Record written observations to the right of each sketch.

   - Beaker 1- Salt
   - Beaker 2- Sugar
4. Now gently stir the contents of each beaker and observe again. Record and sketch your observations. Be sure to view the beakers at eye level so that you can see the interface between the water and the other substances. Observe the solutions for several minutes and record changes. Record written observations to the right of each beaker.

5. Add a few drops of liquid detergent to beakers 3 & 4. Gently stir the contents, observe and record changes.
6. What about any of these results surprised you? Explain.

7. Did the results support your predictions? Explain why or why not.

8. How can you explain the effect of the detergent on the non-polar substances?

9. Continue to add more salt to beaker 1 and more sugar to beaker 2 (in 5 gram amounts). Is there a point at which no more salt or sugar will go into solution? Explain/describe.

   ![Beaker 1- Salt + 5 grams salt (repeat to saturation)](image1.png)  ![Beaker 2- Sugar + 5 grams salt (repeat to saturation)](image2.png)

10. Were you able to add more salt or more sugar to 50ml of water? _______________. Consider what is happening on a molecular level and explain why there is a difference.
F. Extension

1. Begin this inquiry extension with this question to the students: How would the world be different if water behaved like other substances? Encourage students to theorize.

2. Present the following information to the class with your chosen media:
   Water means different things to people. It has unique physical and chemical properties; you can freeze it, melt it, evaporate it, heat it, and combine it.
   Water is a liquid substance made of molecules containing one atom of oxygen and two atoms of hydrogen (H\textsubscript{2}O). Pure water has no color, no taste, no smell, turns to a solid at 0°C and a vapour at 100°C. Its density is 1 gram per cubic centimeter (1 g/cm\textsuperscript{3}), and it is an extremely good solvent.
   All life depends on water. It makes up two thirds of the human body. A person can live without food for more than a month, but can live for only a few days without water. All living things, from the tiniest insect to the tallest tree, need water to survive.
   Water molecules are attracted to each other, creating hydrogen bonds. These strong bonds determine almost every physical property of water and many of its chemical properties also.

3. The method of instruction will be to set up this task as a guided exploration in which students search the web for information on the properties of water. This can be done individually or in small groups. If the class is to work in groups, give group members assignments- investigator, recorder (on paper or on computer), reporter. Inform the class that they will have limited time to complete this activity, and therefore you will be giving them a choice of 4 websites to visit, and that these websites will contain a wealth of water information. Direct the class to pick out a few interesting “facts” about water in their investigation. Inform groups they will have 15 minutes of investigation time and 10 minutes of presentation assembly time. Inform the groups that they will be given 2 minutes to present their findings to the class. Inform the groups they will have the opportunity to present drawings and graphics.

4. Provide the following websites to the class on your chosen media (At the same time inform students that these sites are being provided to give some direction to their investigation and to save time):
   Link B: http://www.uni.edu/~iowawet/H2OProperties.html
   Link C: http://www.sbu.ac.uk/water/
   Link D: http://wwwga.usgs.gov/edu/

5. As each group presents their water facts, the teacher should summarize the findings on their chosen media.

6. Students should record the summation in their Research Logs. Students could also be asked to speculate about how the world would be different if these properties were different.

7. Provide the following summation to bring closure to the student investigation on your chosen media:
   Life depends on the anomalies of water. Especially important is the large heat capacity of water and the fact that living things have a high water content. This contributes to thermal regulation and reduces fluctuations in local temperature. The high latent heat of evaporation gives resistance to dehydration and considerable evaporative cooling. Water is an excellent solvent due to its polarity, high dielectric constant and small size, particularly for polar and ionic compounds and salts. Water has unique hydration properties important
to biological macromolecules (like proteins and nucleic acids) that determine their three-dimensional structures, and hence their functions, in solution.

The freezing of rivers, lakes and oceans is from the top down, thus insulating the water below from further freezing and allowing rapid thawing.

Thermal convection (cold water sinking) causes seasonal mixing in deeper temperate waters. The large heat capacity of the oceans allows them to act as heat reservoirs so that sea temperatures vary only a third as much as land temperatures and thus the oceans moderate our climate. The compressibility that water has compared to many other liquids reduces the sea level by about 40 meters giving us 5% more land.

8. Inform students they will have 5 minutes to write in their Research Logs an answer to the question you are about to pose: What would happen if lakes and rivers froze from the bottom up?

9. For teacher information:

Go To: http://www.sbu.ac.uk/water/. This site gives very detailed technical explanations for the anomalies of water. For teacher information one such explanation follows:
Inquiry 10: Summerhaven Role-playing Debate—The complexities of urban development in sensitive ecosystems

A. Objective:
1. Students will be able to describe the benefits and trade-offs associated with urban development, particularly with regards to stream habitat and water quality.
2. Students will be able to generate an informed opinion about a rapidly evolving, local environmental issue through role-playing.

B. Lesson Overview:
Urbanization and development is a source of controversy and debate. It is important for students to understand that often there is no correct answer to ecological questions. Instead, answers require a careful weighing of the available evidence and the use of personal judgment. This activity connects to what students have learned about habitat and water quality. Connections to other skills involve public speaking, careful listening and critical thinking.

C. Materials / Resources Needed:
- Students should be familiar with terms such as habitat and water quality.

D. Instructions
1. To The Class: “To illustrate the complexity of real-world ecological questions we are going to build on what we’ve learned so far about ecosystems and do a role-playing exercise.” Explain to students that we will present them with a realistic set of circumstances about development around a stream in Summerhaven, atop Mt. Lemmon. They will be playing the roles of concerned citizens at a community meeting. They need to remember to be respectful and to listen carefully to each other’s comments and concerns so that they can make an effective case either for or against the proposed action.

2. Divide the class into six groups. Pass out the scenario page to each. Ask someone to read the paragraph aloud to the class. Ask for questions.

3. Pass out the character descriptions to each group. Ask them to quietly read about their characters and to reflect on what they might say in response to the development scenario. Also, ask the groups to make a sign to place on their desks that says their group affiliation (e.g. “Friends of Sabino Canyon”). Stress to the students that their characters are at this meeting because they have strong opinions about what should be done in their community.

4. Structure a debate so that each group introduces themselves to the other groups and states briefly their position on the issue.

5. Ask various questions of the groups about the plan:
   a. Who has concerns?
b. Who is for building the parking lot and putting the stream in a culvert? Why?
c. Are there comments on this position?
d. What are the advantages/disadvantages of this development plan?
e. If given a choice to only preserve and protect the stream or develop Summerhaven, which one would you prefer? Why?
f. How can we satisfy both objectives of protecting water resources and promoting economic development and jobs?

6. Collect the scenario papers etc. Ask the students to reconsider their original opinions about the scenario. Did anyone change his or her opinion? Why? Did having additional information about various citizens concerns make personal decision easier or harder? Ask them finally to suggest ways that each of the concerned groups might be satisfied by a compromise development plan.

E. Materials
The Proposed Action

A large hotel chain has proposed constructing a new resort on Mt. Lemmon as part of the effort to rebuild the village of Summerhaven. Once built, the hotel and accompanying restaurant will provide 100 jobs and bring new visitors to the village. Plans for the hotel include building a large parking lot to accompany guests and employees. In order to make room for the parking lot, engineers must bury approximately 250 feet of Aspen Creek, a tributary of Sabino Creek, in a culvert. While there are no endangered species living in the stream, riparian habitat is rare in the Catalina Mountains. A public meeting has been called in the village to discuss environmental concerns associated with building the parking lot and putting a portion of Aspen Creek in a culvert.

(Below is information about your character’s role in the debate. This information should direct what your character says, how your character reacts and the way other groups perceive your character during the debate. Imagine yourself this person and what this person believes in. Please embellish these characters in a way consistent with the characters’ core values—it will make the debate much more interesting.)

Group 1
Mt. Lemmon Merchant’s Association

Your group supports the building of the resort in Summerhaven. The resort will bring jobs and visitors to the community. Having enough parking is critical to making visitors happy while visiting the village. You believe the benefits of economic development far outweigh any negatives such as increased pollution from run-off or lost habitat for fish, plants, and birds. The Native Plant Society has approached your group about using a shuttle as an alternative to building a parking lot. Your group is interested in exploring this idea in the meeting as a possible compromise plan.

Group 2
Arizona Native Plant Society

Your group is opposed to the planned construction in Summerhaven because of the potential negative impacts to the plant communities that lives along Aspen Creek. High mountain streams, such as Aspen Creek, are rare in southeastern Arizona and provide habitat for many plants, insects, and animals. Riparian vegetation also plays an important role in removing pollutants in run-off that would otherwise enter the stream. You would like to see the parking lot redesigned in a way that protects Aspen Creek. Possible suggestions include building two smaller parking lots away from the creek or building a shuttle transfer parking lot and offering a park-and-ride shuttle from Tucson.
Group 3
Friends of Sabino Canyon

Your club believes in protecting Sabino Canyon and its tributaries for the enjoyment of future generations. Members of your group consider themselves dedicated environmentalists. You are opposed to any actions that might negatively impact the water quality of Sabino Canyon, including the building of a new parking lot and putting Aspen Creek in a culvert. Your group has come up with a plan to build a wetland downstream of the parking lot where Aspen Creek reemerges from the culvert. This artificial wetland, with its many plants, should help clean pollutants from stormwater run-off. Artificial wetlands are very expensive to build so you're going to insist that the hotel company pay the bill.

Group 4
Western Best Comfort Resorts Incorporated

Your company believes that communities benefit in jobs and tax revenue when you build a hotel. Sure, building a resort has an impact on the environment but isn’t it worth it for economic well being? It is good public relations to consider the concerns of locals and even to compromise a when it is in the interest of the company to do so. You are most likely to consider the concerns and advice of the local merchant’s association over the concerns of conservation groups such as the Friends of Sabino Canyon and the Arizona Native Plant Society.

Group 5
The Sky Island Alliance

Your public interest environmental organization is adamantly opposed to any more large-scale construction on Mt. Lemmon, and is insulted and outraged that a multi-national corporation is willing to sacrifice trees, pave forests, and destroy wildlife habitat in order to make money for their corporate headquarters located in Chicago, IL. Your group believes that the ancient forest and wild animals atop Mt. Lemmon have already faced enough harassment from the previous construction of a military installation, telescopes, ski area, and communication towers. You have serious concerns that the scarce water supply atop Mt. Lemmon is insufficient to support the needs of a large resort and that the current sewage treatment facilities in Summerhaven are inadequate to support this new facility. You fear that in addition to the construction of the parking lot, the resort will have to build new and larger sewage treatment facilities, construct more employee housing in the surrounding forest, and will out-compete and bankrupt the locally owned bed-and-breakfast inn owners who have never been able to sell out every room in Summerhaven, even during the busiest of tourist seasons.
**Group 6**  
The United States Forest Service (USFS)

Since the Aspen Creek is located on federal public land managed by the USFS, your agency must undertake a formal Environmental Assessment as required by the National Environmental Policy Act (NEPA). Your agency must evaluate whether the construction of the proposed parking lot and culvert will negatively affect the public lands where Aspen Creek is located. Since no studies have been conducted yet, you currently have a neutral position. However, as the agency given the responsibility of managing the public’s resources, you are cautious about either supporting or condemning the proposed development until you have all of the facts.

Remember, although no endangered species live in Aspen Creek, you must study the cumulative impact of this action on a broader scale. Among other things, your agency must study whether the proposal will harm breeding and feeding habitat for the endangered Mexican Spotted owl, the potential effect of increased siltation downstream on the endangered Gila chub, potential widespread effects upon the surrounding watershed, native American Indian cultural sites, etc. After thorough research, your agency will distribute the findings to the public and open a comment period for the interested public to submit their ideas and concerns.

**F. Extensions**  
Students can research the impacts of road building and development on streams and write a pamphlet for private-landowners on how to protect their stream.