34. Water Budget Activity

Description: Students will predict and calculate how much water is used from the Rio Grande. Students will make water budget decisions and learn the consequences of those decisions.

Objective: Students will understand the concept of a regional water budget and its complexities.

Materials: calculator

worksheets

Background: Water is a scarce resource in the arid Southwest, and people rely on the river and aquifer for irrigation, livestock, personal consumption, and industrial and commercial uses. Because the Rio Grande flows through three states, Colorado, New Mexico, and Texas, and two countries, the United States and Mexico, the right to use water from the river is regulated by local, state, federal and international agencies. The treaty with Mexico that governs the use of the Rio Grande dates back to 1906. Tribal governments also have water rights.

The Rio Grande Compact (1938) allocates Rio Grande water among the states of Colorado, New Mexico and Texas through a complex set of delivery schedules that relate runoff volumes to delivery obligations at set river index points. During normal water years, New Mexico must ensure that about 60% of the Rio Grande flow passing the Otowi Gage reaches Elephant Butte Reservoir (Crawford, et al. 1993). On average, this delivery requirement is 790,000 acre-feet per year. This requirement is significantly reduced during a drought year. To assure that each jurisdiction receives its share of water, a water budget is developed. A water budget records the amount of water that goes into the system, which

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Grades: 6–12

Time: three one-hour class periods

Subjects: science, math, social studies

Terms: acre-foot, aquifer, evapotranspiration, evaporation, riparian, water budget

includes tributary and ground water sources (the inflow), and the amount of water that is taken out of the system (the outflow).

Although a water budget may seem simple at first glance, the reality is incredibly complex. A water budget is affected by forces over which humans have no control, such as precipitation, weather patterns,and evaporation, as well as by the interests of the environment, agriculture, industry and national, state, municipal and tribal governments. There simply is not enough water for all the competing interests that a water budget has to satisfy.

Note: In order for students to gain an understanding of the complexity of water budgets, it is strongly suggested that all three sections of this activity be completed.

Terms:

water budget: A summary that shows the balance in a hydrological system between water supplies (inflow) to the system and water losses (outflow) from the system. It is a common reporting tool for water-resource systems.

riparian: relating to or living or located on the bank of a natural fresh watercourse such as a river, stream, pond or lake.

evapotranspiration: a term that includes the portion of precipitation being returned to the atmosphere either by direct evaporation or by transpiration through vegetation, with no differentiation being made between the two processes.

evaporation: the change from liquid or solid to vapor; water in a lake evaporates into the air.

acre-foot: a quantity of volume of water that covers one acre to a depth of one foot; equal to 43,560 cubic feet, 325,851 gallons or 1,233.48 cubic meters.

aquifer: the stratum or rock below ground that bears water, typically in a location capable of producing water usable by humans, such as from a well.

Procedure: **Part I**

1. Brainstorm with students where the water in the river comes from. Answers include:
   rain (and all forms of precipitation)
   melting snowpack
   inflow from tributaries
   run-off from urban storm drains
   aquifer (shallow and deep)

2. Explain that the river and the aquifers are not closed systems, independent from one another, but instead are connected. The shallow aquifer discharges water into the river, and the water in the river flows into (recharges) the shallow aquifer. Below Elephant Butte Dam, the major aquifers are the Rincon Valley Basin, the Mesilla Basin, the Jornada del Muerto Basin and the Hueco Bolson. They provide ground water for communities and industry in New Mexico, Texas and Mexico, and they help meet agricultural demands during drought years when surface water is insufficient. The growing communities of Las Cruces, El Paso and Ciudad Juarez are increasing their use of these aquifers. Continued population growth may strain the abilities of these basins to meet demand in coming decades.

3. Brainstorm with students: who are the water consumers along the lower Rio Grande in New Mexico, Texas and Mexico? Who takes water from the river? Who uses ground water? Why doesn't everyone use either ground water or river water? Some possible answers are:
   residential use (personal consumption, lawns, dishwashing, laundry, etc.)
   agriculture
   livestock
   commercial (office buildings, stores, etc.)
   industry (factories)
   governments
   evaporation
   riparian evapotranspiration
   aquifer recharge
   downstream users
   aquatic wildlife (fish, etc.)
   terrestrial wildlife (deer, etc.)

   There isn't enough water in the Rio Grande to meet demands. Water is set aside for specific uses, mostly agriculture and meeting obligations to downstream users in Texas and Mexico.

4. Introduce the idea of a budget. When do people use a budget?

What do you think a water budget is? How would you know if a water budget is balanced? Discuss the needs of upstream users: how do those in the Middle Rio Grande Valley affect those below Elephant Butte Dam? Why should a water budget in the Middle Rio be of concern to users in the Lower Rio?

5. Assign students to work in groups of two or three. Pass out Worksheet I to each group. Have students determine the acre-footage of water budgeted to each Middle Rio user category based on the percentages and acre-feet on the worksheet.
6. Discuss with students whether the requirements of the Rio Grande Compact have been met and how upstream use affects the amount of water available downstream.

Part II

1. Continue with the concept of a budget. While the Middle Rio Grande has a water budget that helps deliver water to users below Elephant Butte Dam, the Lower Rio does not yet have a budget. Students will try their hand at creating a water budget for the Lower Rio based on data from the year 2000.
2. Pass out Worksheet II. Have students predict the percentage of water used for each category using Worksheet I as a guideline. Have students answer the first two questions.
3. After discussing their answers, provide students with the actual percentage, including that by source (ground water, surface water or both). Follow with a discussion about where our water comes from and how it's used. Were they aware of the amounts and the primary sources? Did they notice any categories missing from Worksheet I?

Part III

1. Pass out Worksheet III.
2. Discuss drought and how it affects water flow in the river.
3. Have students allocate the remaining water and figure out the percentages.
4. Discuss consequences using notes below.

   If agriculture in New Mexico is less than 416,100 acre-feet: there is not enough water to support all the agricultural needs along the Lower Rio Grande. In the West, senior water rights holders get their surface and ground water first during drought years . Junior rights holders may get no surface water at all,and may get only limited ground water once the rights of senior users are met. Growing cities are increasingly tapping ground water sources to meet residential demands.

Reservoir evaporation is highly variable depending on the surface area of the reservoir and local climate over the long term. Rates are usually at their highest when reservoirs are full, leaving a larger surface area from which water can evaporate. Elephant Butte and Caballo Lakes are located in a hot, dry, windy area that has among the highest evaporation rates in New Mexico. Some people have considered storing more water at northern reservoirs (El Vado and Abiquiu Lakes, for example) where cooler temperatures and higher humidity tend to reduce evaporation rates.

Currently, residential, business and government use is almost strictly ground water. But cities are in the process of purchasing surface water rights from those holders willing to sell. Cities like Phoenix, AZ, and Denver, CO, have purchased surface water rights from farmers hundreds of miles away. Could Las Cruces and El Paso be planning the same? If you were a farmer, at what price would you be willing to sell your water rights (which means giving up some or all of your farming business)? As populations in the Southwest continue to grow, will ground and surface water be enough to meet the demand?

If water to Texas is less than 313,900 acre-feet, the Rio Grande Compact obligations are not being met. New Mexico will begin to accrue a water debt which will have to be met when (and if) wetter conditions return. Farmers around El Paso will face the same restrictions and senior versus junior allocation conflicts that New Mexico farmers will. In both cases, some farmers may have to leave their land fallow; others may have to sell land. Ways that farmers could adapt to less water may be to plant crops that require less water or develop more efficient methods of watering (i.e., drip irrigation instead of sprinklers). How else could farming in the desert be made more water efficient?

If water to Mexico is less than 60,000 acre-feet, obligations under the 1906 Treaty are not being met. Mexican farmers depend heavily on this water, and in most years this amount is met as farms in New Mexico and Texas return unused water to the Rio Grande. During prolonged drought, this amount may be reduced somewhat but, as with Texas, a water debt will accrue that will one day need to be met.

Riparian evapotranspiration is a factor that is not generally counted in Lower Rio Grande water management plans. This is the amount of water—generally ranging from 20,000 to 50,000 acre-feet per year—that is used by riparian vegetation. This factor cannot be controlled in the same way that human consumption may be. There is no "switch" to turn off riparian evapotranspiration. In fact, during a drought year, riparian

trees and plants may use more river water because they are receiving less water in the form of rain. One way to reduce evapotranspiration is to remove water-thirsty non-native species, like saltcedar. This work is already being done at Bosque del Apache National Wildlife Refuge near Socorro,and at Mesilla Valley Bosque State Park in Mesilla. Water savings at Bosque del Apache have reached 20 to 30%.

The point of this activity is not so much that students create workable water budgets, but that they gain an understanding of just how complicated the process can be.

Extensions:

1. Make a pie chart for the Year 2000 Data provided for this exercise.
2. Develop the following scenario and have students debate the pros and cons.

   The City of Las Cruces is growing rapidly and must supplement its ground water supplies with river water. (This is due to happen in Albuquerque by 2008, and the City of Las Cruces water utility is already purchasing surface water rights.) The southwestern willow flycatcher is a small migratory bird that needs thickets of riparian vegetation for nesting. With the removal of most vegetation between the levees, nesting sites have become limited and it is now federally listed as an endangered species. The restoration of native willow thickets may be limited by prolonged drought or water rights concerns, and the removal of saltcedar may further decrease this bird's nesting options.
3. Have groups take one water consumer and propose a way to reduce water usage, listing pros and cons.
4. Have students collect news stories about the Rio Grande's water users.
5. See the "How Deep Is the Water Table?" activity in the Middle Rio Grande Guide for information about how the river is connected to the aquifer.

References:

NM State Engineer, "Summary of Water Use (in acre-feet) in Rio Grande Basin, 1995." www.seo.state.nm.us/publications/wrri/wateruse/basin95/rg.html

"2000 Summary of Water Use by County," State Engineer

New Mexico Lower Rio Grande Regional Water Plan. 2004. Lower Rio Grande Water Users Association (LRGWUA)

Teacher Key for Water Budget Worksheets

Water Use in Doña Ana and Sierra Counties in 2000

Use	Percent of Total	Source	Acre Feet	Note
Agriculture	65%	ground: surface: total	113,526 437,879 551,420	79% from surface water; irrigated agriculture = 91% of water use in Doña Ana *
Reservior Evaporation	29%	surface	245,064	Second highest consumer of water in Lower Rio Grande #
Residential	5%	ground	43,935	Growing urban areas may buy surface water rights
Business and Government	1%	ground: surface: total:	7,910 154 8,064	Most used commercially
Total	**100%**	**Ground:** **Surface:** **Total:**	**165,421** **683,695** **849,383**	20% from ground water; 80% from Rio Grande
Not included in totals above:				
Environmental Use		ground	50,000	25,000 to 60,000 acre feet per year between Caballo Dam and Anthony ^
River water to Texas		surface	313,900	Required by Rio Grande Compact of 1938; reduced during droughts
River water to Mexico		surface	60,000	Required by 1906 Water Treaty; reduced during drought

* NM is allocated 416,100 acre feet per year of Rio Grande water by 1938 Rio Grande Compact.

Varies from year to year depending on reservoir size and climate conditions.

^ Use of water by vegetation (riparian evapotranspiration)

Data based on 2000 Summary of Water Use by County, report by the Office of the State Engineer (www.ose.state.nm.us) and The New Mexico Lower Rio Grande Water Plan, 2004.

Water Budget Worksheet I

Middle Rio Grande Water Budget

The Rio Grande Compact is an agreement among Colorado, New Mexico and Texas that regulates the allocation of river water. It also reaffirms an annual water delivery to Mexico that was established in the 1906 Water Treaty with that nation. As it relates to the Middle Rio Grande Valley in New Mexico—defined as the reach from the Otowi river gage (near Los Alamos) to Elephant Butte Dam—the Compact stipulates that during an average water year at least 790,000 acre-feet of water must be delivered annually from Elephant Butte for use downstream. The water budget in the Middle Rio Grande Valley helps meet this delivery of water to users below Elephant Butte Dam. During drought years, these percentages are adjusted to provide a delivery of 350,000 ac-ft.

The table below lists several categories of water users in the Middle Rio Grande Valley and the percentage of water budgeted to each in an average year. Using 1,424,000 acre-feet (ac-ft) as the total amount of water available (from the river, tributaries, ground water and storm drains) calculate the acre-feet allocated to each category. Round up to the nearest whole number. Does the water budget below meet the Rio Grande Compact requirements?

1 acre-foot = a quantity of volume of water that covers one acre to a depth of one foot; equal to 43,560 cubic feet, 325,851 gallons, or 1,233.48 cubic meters.

Use	Percentage	Acre Feet
Agriculture	8.4%	
Open-water Evaporation	4.9%	
Riparian Evapotranspiration	11.5%	
Evaporation from Elephant Butte	12.0%	
Residential Use	4.9%	
Business and Government	2.7%	
Water Left in River (Rio Grande Compact)	55.6%	
Total	**100%**	**1,424,000**

Water Budget Worksheet II

Water Sources and Users in the Lower Rio Grande

There are many demands on the Rio's water, including agriculture and growing cities in New Mexico, Texas and Mexico. Ground water is also an important source, especially for cities like Las Cruces and Ciudad Juarez.

Put yourself in the position of a water authority that needs to develop a water budget for the Rio Grande between Elephant Butte and El Paso. Using Worksheet 1 as a guide, determine what percentage each category should use and write your answers in the Prediction column. Your total percentages must equal 100. Answer the first two questions when you're finished.

Your teacher will then give you some actual data, including water sources, from the New Mexico Office of the State Engineer for the year 2000. Enter this data into the appropriate remaining columns and use it to answer the remaining questions.

Use	Prediction (%)	Actual Percentage	Source Ground	Source Surface
Agriculture				
Reservoir Evaporation				
Residential Use				
Business & Government				
Total	**100%**	**100%**	____%	____%

1. In your prediction, who uses the most water? Explain your answer.
2. Who do you think will use the least water? Explain your answer.
3. Answer the following questions after your teacher tells you the actual percentages for 2000.
   i. How do your predictions compare with the actual percentages?
   ii. Were you surprised by any of the percentages? Why?
   iii. Along the Lower Rio Grande in New Mexico, water comes from two sources: the river (surface) and groundwater. Which source provided most of the water above? Did you discover something new about where we get water along the Lower Rio Grande?"

Water Budget Worksheet III

Dividing Water During a Drought

In 2000, 683,695 acre-feet of surface water was used in Sierra and Doña Ana Counties, which accounts for 80% of all water used that year. This was a slightly below average flow year for the Rio Grande, but not a severe drought year. Imagine now that a prolonged drought has reduced the amount of available water in the Rio Grande to 515,000 acre feet. Using Worksheet II as a reference, create an adjusted water budget to reflect this severe shortage, keeping in mind the following:

The 1906 Treaty with Mexico requires an annual water delivery to Mexico of 60,000 acre-feet of Rio Grande water, which may reduced during drought.The 1938 Rio Grande Compact divides Rio Grande water on a 57% (NM) to 43% (TX) basis, even in drought years. Under the Compact, New Mexico is allocated 416,000 acre-feet of Rio Grande water and Texas is allocated 313,900 acre-feet. This will irrigate a maximum of 160,290 acres in both states in a normal year. If reservoirs are smaller during droughts, there is less surface area from which water will evaporate. When reservoirs are full, evaporation rates may be at their highest.

Work together as a group and determine the best distribution of water for Lower Rio Grande water users that will equal 100% and 505,000 acre-feet. Answer the questions below once you or your group is finished with the table.

Use	Percentage	Acre Feet
Agriculture in New Mexico		
Reservoir Evaporation		
Residential Use		
Business & Government		
Water to Texas		
Water to Mexico		
Total	**100%**	**515,000**

How did your surface water percentages differ from Worksheet II? Who received the most water and why?

Who or what consumes water along the Lower Rio but is not reflected here? How would a drought affect them?

How do you decide who gets water in the event of a long and severe drought? Who do you think are the most important users and why?

Discuss what water use may look like in 10, 15 and 50 years. If growing cities demand more water, where will it come from? What advances in conservation practices, technology or hydrology may make a difference?