NCEP Network of Conservation Educators & Practitioners

Developing capacity to sustain the Earth's diversity

NPS/Mike Quinn

The Colorado River provides water for agriculture, households, hydropower production, industry, recreation, and wildlife, and each of these uses has economic value. As population in the southwest United States has grown, and irrigation demands have increased, the overall consumptive use of the river is now roughly equal to the renewable supply. Looking to a future climate in which Colorado River flow diminishes in the face of increasing demand, society will have to make choices between competing economic activities.

These choices will be impacted by the economic value of water uses and by the water rights associated with each use. The economic value of a water use can be determined by how much benefit a user gets, and by what they are willing to pay for that use. Water rights are also especially important and play a large role in the Colorado River Basin. Water rights were handed out on a "first in time, first in right" basis which resulted in agricultural districts having the right to a majority of the Colorado River's water. In addition to having a right to the largest amount of water, they also have the highest priority water rights. This means that if there are shortages (i.e. not enough water for everyone) in the basin, the lower priority municipal users must curtail their use before the agricultural districts will have to reduce their usage.

Although agricultural use has a right to more water and at a higher water right, it generates considerably less economic return per given amount of water. As supply decreases and demand increases in the future, we're likely to see a shift of some agricultural water to urban settings. This shift will be affected by the economic value of the water uses, and by the water rights of each user. We'll explore this more in the unit below and then, at the end, we'll use the Economics Simulator to explore some different potential policy options.

Lesson Outline:

1. Types of Water Use
    - Instream Use
    - Offstream Use
        - Municipal
        - Agricultural
2. Value of Water
3. Market Prices or Water Rights?
4. Increasing Populations and Water Rights
5. Economics Simulator - Interactive Simulation

Types of Water Use

Use of Colorado River water can be classified into two different categories: instream and offstream use. Instream use refers to the use of water within the river, for things like recreational activities and hydropower generation, and the value derived from those uses. Offstream use is the use of water that is taken out of the river, for activities like agricultural and municipal use, and the value derived from those uses.

Instream Use

The Colorado River provides a variety of uses as it flows over 1,400 miles from its sources in the Rocky Mountains to the Gulf of California. The watercourse itself is home to habitats supporting warm and coldwater aquatic species, both in free flowing sections and in numerous large reservoirs. At the dams forming reservoirs such as Lake Powell and Lake Mead are hydropower plants producing carbon-free electricity used by several million people. Millions of people take advantage of the river and its reservoirs for a variety of recreational activities. Inflows of pristine water from mountain sources ensure that the water quality of the Colorado River is maintained. In each of these aspects, the simple presence of water in the river provides value to users. Water remains in the river, and every drop is enjoyed and used again by those downstream. These so-called instream water uses can be shared again and again.

Important instream uses in the Colorado River

Reach	Use
Headwaters	wilderness values and habitat coldwater river fishing rafting and kayaking water quality
Reservoirs	water storage hydropower boating & fishing
Downstream reaches	endangered species habitat rafting & kayaking
Delta	critically endangered habitat

Types of Water Use – Continued

Offstream Use

Colorado River water is of course also used offstream. Water is diverted to irrigate crops and be delivered to cities. The river's water cools power plants and irrigates golf courses. Most of the diverted water ends up as water vapor released through the leaves of plants (called evapotranspiration), or evaporates more directly. Some makes it back to the river to be reused, or ends up flowing to the ocean or other sinks where it cannot be reused. These latter flows are called return flows.

Agricultural

Most offstream use supports irrigated agriculture. In the Colorado River Basin, three quarters of irrigation water is devoted to forage crops that support livestock. A smaller acreage, mostly located in favorable climates and soils, supports grains, fruits, and vegetables, which are consumed directly by people. In the Colorado River Basin somewhat over half of the water diverted for agriculture is used to support crop growth. The remainder (return flows) may be available for reuse, but their availability depends critically on local conditions. While irrigation technology can reduce diversions and increase return flows, it cannot reduce evapotranspiration requirements. In total, about 80% of offstream water in the Colorado River basin is used for irrigated agriculture.

Municipal

The remaining 20% supports the ever-growing metropolitan regions. Most of this remaining offstream water is used by households, both inside and outside of the house. Outside uses are similar to those of agriculture: primarily for irrigation. Inside, the major uses are for toilets, showers, and clothes and dish washing. As a rule of thumb, half of household water use is outside and half inside. Importantly, the half used outside is mostly lost to evapotranspiration, while the great majority of indoor use generates return flows potentially available for reuse. Industrial and commercial uses make up the remaining municipal use.

Can you pick out which uses are agricultural and which are municipal from the pictures?

Value of Water - NROVC

Water uses have economic value because people gain benefits from the resource. Whether for crops, lawns, showers, hydroelectric power, habitat, or pure aesthetics, water is valuable. For each specific use at a particular time and place, it is possible to estimate the economic value of the water used. One common method that economists employ to determine this value is called Net Return Over Variable Costs, or NROVC for short.

The NROVC for different uses can be determined by subtracting the cost of an activity from the economic return of the same activity. For example, a farmer receives around $150 for the amount of alfalfa he can grow with an acre-foot of water, and it costs him $90 to produce that crop, so the NROVC for an acre-foot of water used to grow alfalfa is $60. Fruits and vegetables usually have a much higher NROVC because they can be sold for considerably more than alfalfa or other forage crops. The amount of lettuce that can be grown with an acre-foot of water is sold for around $2000, but that amount of lettuce costs around $600 to grow, leaving an NROVC of $1400. Naturally, farmers try to maximize their NROVC, but often climate and soil conditions dictate whether they grow crops like alfalfa that have a lower NROVC. Additionally, the government subsidizes farmers for growing some low value crops (usually cotton and wheat), so even though they barely make a profit (and often lose money) the government subsidy will result in the farmer making a profit.

Municipal water use has a much higher NROVC than agricultural water use because a much smaller amount of water can provide a significantly greater economic benefit. There are a wide range of commercial and industrial uses, but economists have estimated that the average NROVC for these is around $500 and $750, respectively, per acre-foot. The NROVC of residential indoor and residential outdoor water use is often harder to estimate because they're not used to create a product. Because of this, economists use other methods to estimate production value, including determining what people are willing to pay to obtain the water needed for each use. Indoor residential water use has a higher NROVC than outdoor residential use because although the cost of supplying that water to the home is the same, we receive much more value from the water used inside the house. For example, what would you be willing to pay for 100 gallons of water (enough to use the shower, toilet, and sink for a day), versus what would you be willing to pay to water the lawn for 5 minutes? The generally accepted value for an acre-foot of residentially-used water from Colorado River is $1000 for outdoor use and $4000 for indoor use.

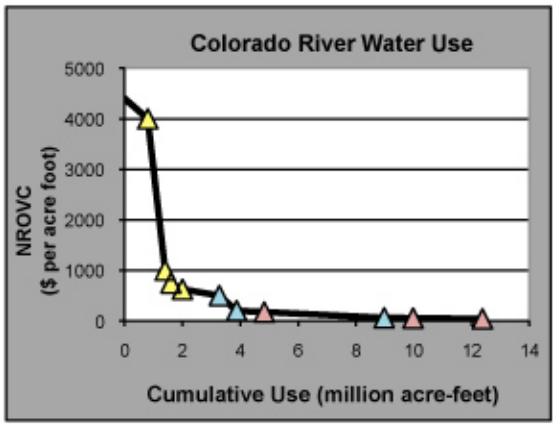
Value of Water – NROVC continued

Above, we discussed a couple of examples of NROVC for Colorado River water, but let's look at a figure that has the nine main uses on one graph. The numbers in the left column of the table below represent the amount of water used in each of the nine uses, the "cumulative use" value in the center column is a running sum of the amount of water used for all main uses listed, and the column on the right has the NROVC of each use. The uses are arranged from highest NROVC to lowest NROVC. The cumulative use value in the middle table is a running sum of all the uses. For example, the cumulative use in the first row is just equal to that use, but the cumulative use in the last row is equal to the sum of all the uses. Cumulative use is the x-axis on the graph, while NROVC is the y-axis.

Although most of us are not used to seeing this type of graph, it can be helpful in illustrating what the economic return is for different amounts of water use. We can see that the top one million acre-feet of water used has a value of $4000 per acre-foot, and that the first three million acre-feet have a value of over $500 per acre-foot. The right end of the graph shows us that the economic return on the bottom two or three million acre-feet of water is pretty low. Because NROVC is so low, it is hard to see in the graph, but looking back at the table we can see that the NROVC is around $40 per acre-foot.

Water use type, cumulative use and, NROVC - Cumulative uses are sorted by NROVC on the table and graphed on the chart.

Type of Use	Amount used per type (MAF)	Cumulative use all types (MAF)	NROVC of use ($/MAF)
Residential - Indoor	0.8	0.8	4000
Residential - Outdoor	0.6	1.4	1000
Industrial	0.2	1.6	750
Commercial	0.4	2	625
LB Fruits/Vegetables	1.28	3.275	500
LB Cotton	0.96	3.875	200
UB Corn, barley, other	0.6	4.83125	175
LB Alfalfa/Wheat	4.14	8.975	60
UB Alfalfa	1	9.975	55
UB Grass, hay, pasture	2.4	12.375	40
Key:	Municipal	Upper Basin Agriculture	Lower Basin Agriculture



Market Prices or Water Rights?

The NROVC for different uses of water is essentially the same as what a user would be willing to pay for that water. Using the example of the alfalfa farmer that makes a $60 profit for every acre-foot of water he uses, as long as the price of water is $60 per acre-foot or less, it is profitable for the farmer to grow alfalfa. This same correlation between NROVC and what a water user is willing to pay holds for all the other uses of water; a steel mill would pay $500 per acre-foot while a homeowner would pay $4000 per acre-foot for indoor use. If municipal water users are willing to pay so much more for water, then why don't we see a shift in water use away from low value agricultural to high value municipal? There is not a shift because the use of Colorado River water is controlled by water rights that have been handed out over the last century.

Water Rights

Water rights for Colorado River water were appropriated under a "first in time, first in right" principle, and most of the agricultural districts were well established before any of the cities applied for water rights. This resulted in agricultural districts having the water right to 90% of the river's water. Equally important as having a right to the majority of the river's water is that the agricultural rights were appropriated first and are therefore senior water rights. If a shortage is declared in the basin these senior water rights will be the last to have shortages while the lower water rights holders (mostly metropolitan areas) will have to curtail their use. In addition to specifying the price and amount of water to be delivered, the water rights are permanent and cannot be renegotiated.

In most cases an individual farmer cannot sell water to a user external to his irrigation district without the concurrence of his irrigation district. Moreover, due to the Colorado River Compact, the interstate sale of Colorado River water is prohibited. Irrigation districts have also resisted the sale of water to urban users for several other reasons including loss of control over a resource that only grows in value over time, and because of impacts to the local economy. In California, for example, the board of the largest agricultural district (which has rights to nearly 20% of the entire Colorado River's flow) is elected by citizens rather than landowners, so they vote in the interest of a broader set of concerns.

Increasing Populations and Future Water Use?

Although these water rights are recognized in law and cannot be renegotiated, as urban populations and the price they are willing to pay for water have increased, we have started to see shifts in agricultural use to municipal water use. These shifts fall into two categories:

1. long-term transfers during normal conditions
2. short-term transfers during droughts conditions (called forbearance agreements)

A good example of a long-term transfer is from 2002, when the federal government threatened to find that California's largest agricultural district was wasting water and thereby in violation of the Colorado River Compact, and consequently forced them to enter into a long-term lease with the City of Los Angeles as their only alternative to losing the water. This resulted in a substantial transfer of water from agriculture to the urban Pacific Coast. This is an example of a long-term transfer of water under normal (non-drought) conditions.

The short-term transfers starting to be seen are the voluntary transfer of water from agricultural use to municipal use during drought conditions. Municipal water rights are the lowest, so when a shortage is declared, they would normally be the first to have to reduce their usage. But under these drought transfers farmers volunteer to bear the shortage and the municipal areas are permitted to use the farmers' water. These types of transfers are called voluntary irrigation forbearance agreements. Crops that have the lowest NROVC are usually targeted for forbearance since this water can be purchased the least expensively.

These two transfer mechanisms are the focus of the Excel-based Economics Simulator.

Exercise

1. What use is generally divided into "instream" and "_____" use. [redacted]

2. Which is not an example of "instream" use? [redacted]

3. A user would be willing to sell their water for seomthing _____ than their NROVC? [redacted]

4. Which use typically has a higher NROVC; alfalfa or vegetables? [redacted]

5. What has a higher average NROVC; agriculture or municipal? [redacted]

6. Who is the last to receive shortages in times of drought? [redacted]

7. Water rights specify the _____ of a water delivery? [redacted]

8. Some urban areas are leasing water from _____ districts to meet their rising demand? [redacted]

9. Transfers of water from agricultural to municipal user during drought conditions are called _____ agreements? [redacted]

Economics Calculator

Download the Excel-based interactive and jump to the end of the Unit to explore the Economics Calculator

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