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Lower Colorado River Basin Salinity Control Resources

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by

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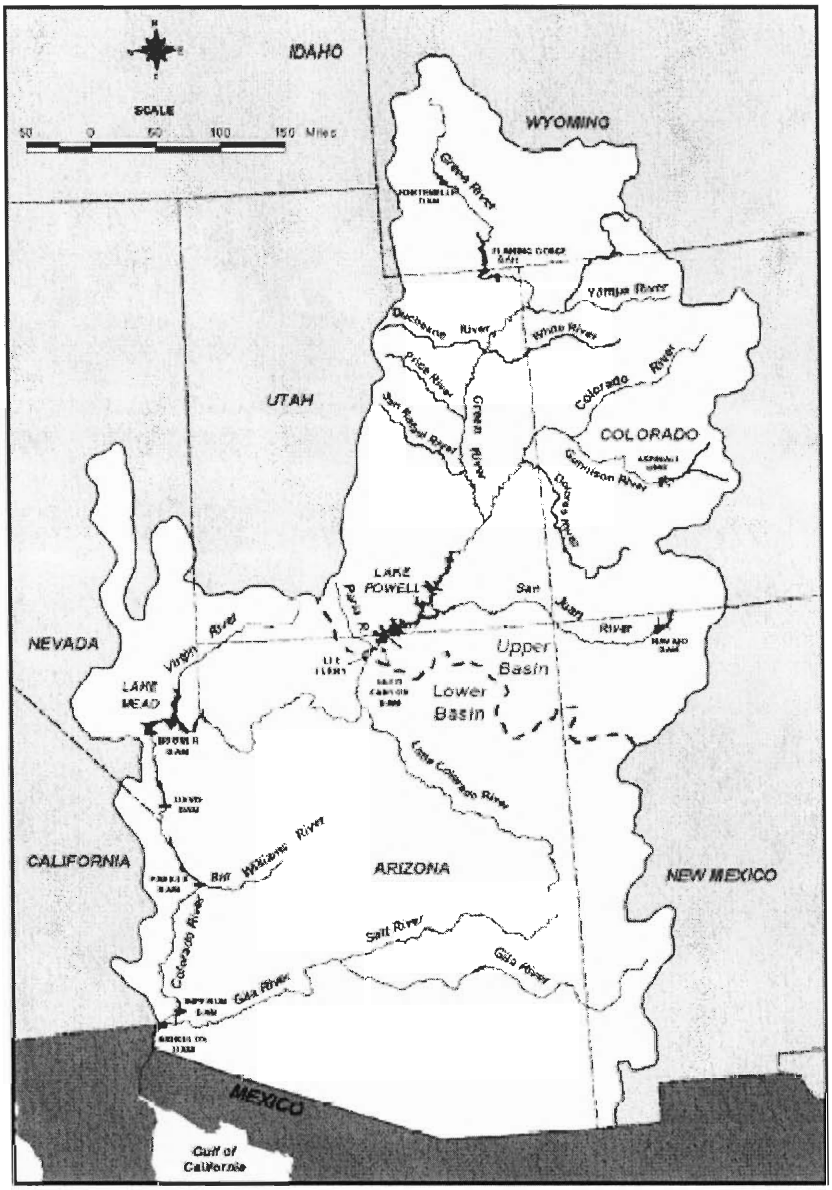

Abstract

Agricultural runoff into the Colorado River causes a downstream increase in water salinity. Salinity of the Colorado River increases from 50 milligrams per liter in the headwaters of the river to over 900 milligrams per liter at the international boundary between the United States and Mexico. This salinity increase is due to three major sources, these being the natural salination of water from salt mines, fertilization runoff and manure runoff. However various measures and practices exist to reduce the amount of dissolved salts leeching into the soil. This project analyzes various measures that can be utilized to decrease river salinity.

Introduction

The Colorado River originates in the Rocky Mountain National Park of Colorado and flows through Utah, Arizona, Nevada, California and Mexico to empty into the Pacific Ocean through the Gulf of California. Through millions of years of unrestricted flow, the river has contributed to the existence of some of the most magnificent geological features in North America. Aptly named the Red River by early Spanish explorers because of the red sediment contributed by eroded sandstone, it was not renamed the Colorado River at the request of the State of Colorado until 1921. Its flow has changed dramatically since the 19th century with the introduction of over 53 dams on the river and its tributaries. Along the way, its basin drains thirty-four Indian reservations, a quarter million square miles of land in seven states and parts of Mexico, providing water for twenty-five million people, twelve billion kilowatt-hours of electricity, and three million acres of irrigated land.

As the river flows out of the Rocky Mountains its salinity increases to well over 600 mg/L, relatively minor compared to that of ocean water (nearly 35 g/L,) but exceptionally large when compared to that of freshwater lakes such as Balkhash Lake in Kazakhstan (3 mg/L) and even the Aral

Lake in Russia (over 10.5 mg/L). The EPA safe-drinking water limit is 500mg/L. The river gets loaded with approximately 9 million tons of salt each year, only half of which is attributed to natural sources such as erosion and saline springs. The rest is a direct result of agricultural, municipal and industrial runoff.

Natural Salinity

The natural salinity of the Lower Colorado River Basin was estimated by the Environmental Protection Agency to be 334 mg/L. This results from the natural diffusion of salts from underlying soils, geologic formations and stream channels into the river over its large drainage surface area. Most of these salts were deposited in the region millions of years ago in the ancient saline marine environment. Saline springs at the Glenwood-Dotsero area above the Grand Junction in Colorado and the Paradox Valley springs in Montrose Country, Colorado contribute a combined salt load of nearly 650 tons per year. Considering the size of the irrigated area at these sites (Glenwood-Dotsero irrigates less than 20 square miles of land, See Fig 1) provides a glimpse of the how even a relatively small area of land (the Colorado irrigates over 2.75 million square miles) can have a drastic impact on river salinity.

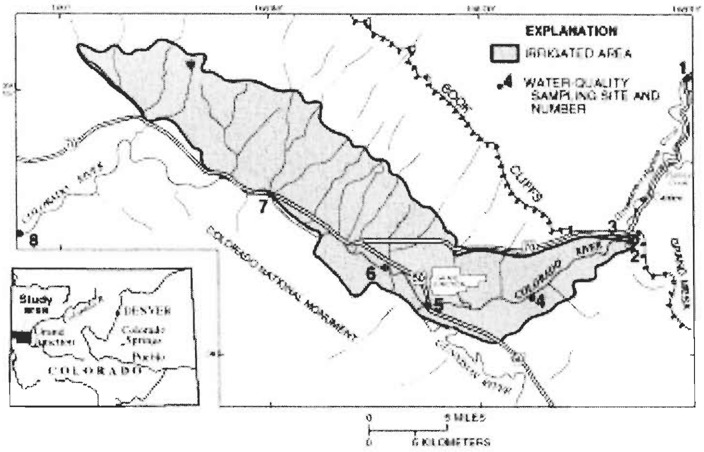

Figure 1. Irrigated area in the Grand Valley and locations of sampling sites for the 1994-95 salinity study of the Colorado River. (8)

Other Sources

Natural sources only contribute to an estimated 47% of Colorado River salinity. The rest comes from human use of the river and its surrounding land. Figure 2 shows the relative impacts of human use on river salinity. The majority of salt load from unnatural sources comes from agricultural use of land (37%). Reservoir evaporation and industrial and municipal uses contribute the remainder.

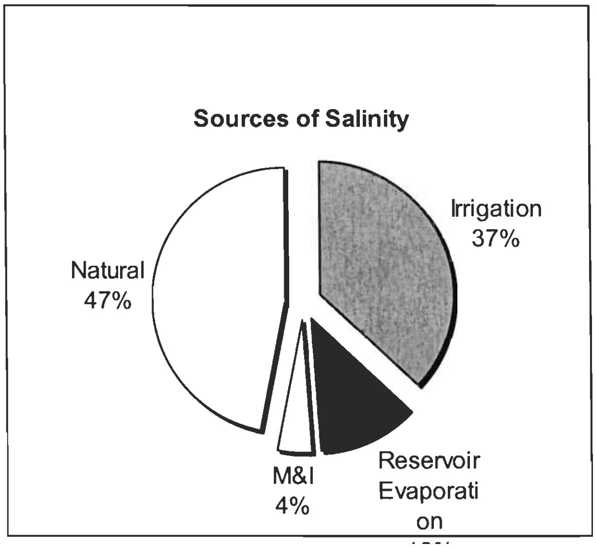

Figure 2: Sources of river salinity.

Effect of Mining of Water Salinity

Many aquifer saline deposits, although are capable of transmitting water, are enclosed in hundreds of feet of shale, a clay-like fine sedimented layer, that is impermeable to water. The enclosure allows ground water to circumvent the deposits without the associated pick up of salt. Mining of coal, oil, gas and coal bed methane in the region disrupts the shale enclosure and increases deposit contact with water, thus allowing the mobilization of previously static saline deposits. (7) Mining also increases soil erosion introducing more sediment and accompanying minerals into the water.

Besides the exposure of saline sources to river contact, the development of energy resources contributes to river salinity by the introduction of highly saline water, a byproduct of oil and gas production, into the river. The increased salinity of this water is due to the dissolution and precipitation of minerals in the rocks and other chemical reactions that occur between water and minerals under high temperature and pressure in the subsurface (11). The increase in saline water production with the increase in the production of oil in Prudhce Bay, Alaska is shown below in Figure 3. The figure makes it apparent that advances in oil production over the past two decades have increased, instead of decreasing, saline water output of the process.

As resources closer to the surface become depleted, miners are forced to dig deeper and deeper into the ground. Hydrocarbons obtained from deeper sources often result in higher saline water production, except in areas rock has higher consistency of shale and siltstones where fresh water is often found at greater depths. Figure 4 shows the relationship of mining depth to water salinity in several locations throughout the United States, but suggests that such is not a significant problem in the Southwest.

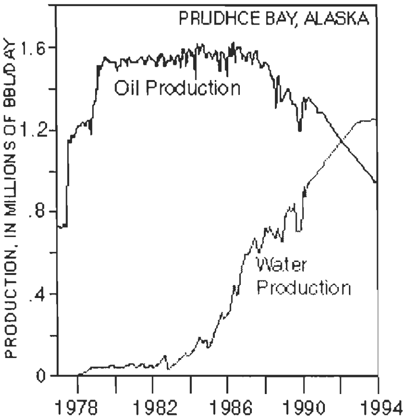

Figure 3: Oil Production and its relationship with the production of saline water. (11)

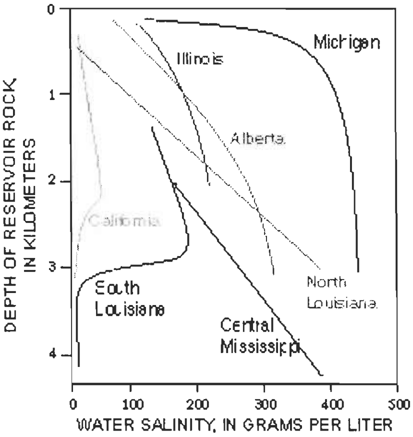

Figure 4: Mining depth and its relationship on produced water salinity.

Municipal and Industrial Sources

W.V. Iorns, in a 1965 report entitled *Water Resources of the Upper Colorado Basin* estimates that M&I users contribute 100 tons of salt load per 1000 people. The population in the Lower Basin s estimated at over 4,000,000 people, resulting in 400,000 tons of salt load yearly. Nevertheless, municipal and industrial sources are relatively low in salt concentration when compared to that produced by natural sources and agriculture and are also the most expensive to control.

Solutions:

Presently, several methods are in place to reduce the salt content of the Colorado River. These include lining of irrigation return canals with cement to prevent water from leeching into soil and the use of desalination plants to filter salt and sediment from the water. The United States Bureau of Reclamation (USBR), established in 1902 to manage the country's water resources, is responsible for the rivers salinity control programs as well as the construction and maintenance of dams in western states. To help cope with the salinity problem in the Colorado River, the USBR established the Lower Colorado Region Salinity Assessment Network (LCRSAN), an organization of local action agencies dedicated to the monitoring, control and abatement of soil salinity within the irrigates agricultural areas of the Lower Colorado River Region. The purpose of the program is to design an effective irrigation management strategy through supplying local action agencies with proper training and tools required to inventory, monitor and assess the regions salinity problems to develop optimal irrigation practices.

To reduce seepage of Colorado water into soils from the 82-mile All American (Figure 1) and the 150-miles Coachella

Canals, which both decreases water availability and contributes to the salinity problem because of dissolved salts picked up by leached water, the Bureau of Reclamation has decided to construct a 23 mile-long concrete lined canal that would run parallel to Pilot Knob to Drop 3 of the canal shown on Figure 1.

According to Bureau of Reclamation's conclusions contained in its March 1987 "All-American Canal Relocation Study: Hydrologic Appendix" and its March 1994 "Final Environmental Impact Statement/Final Environmental Impact Report for the All-American Canal Lining Project: Geohydrology Appendix," the construction of the canal will prevent the seepage of nearly 70,000 acre-feet of water into the soil. The lining of a 1.5 mile section of the Coachella Canal will prevent seepage of another 28,000 acre-feet, reducing the total seepage from the canal to just under 100,000 acre-feet of water.

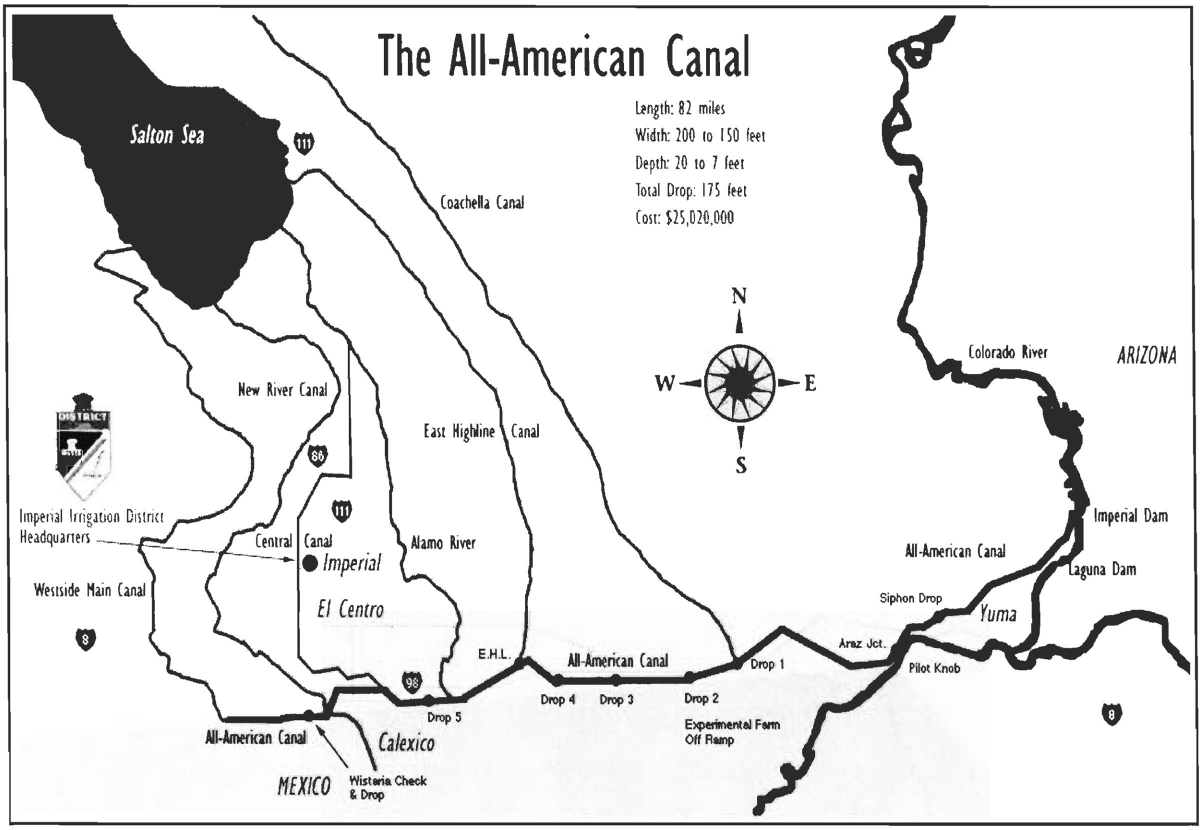

Figure 1: Map of All-American Canal

Yuma Desalting Plant

The majority of the salt load removed from Colorado River water occurs at the Yuma Desalting Plant, the largest plant of its kind in the world, in Yuma, Arizona through the process of reverse osmosis. The Yuma Reverse Osmosis Desalting Plant was constructed in 1992 to help the United States meet salinity requirements for Colorado River water delivered to Mexico by desalting and salvaging drainage water that would otherwise be too saline for delivery, thereby saving the United States a yearly 78,000 acre-feet of water.

Osmosis is the process by which solutions move from an area of low solute concentration to an area of high solute concentration through a semi-permeable membrane. A semi-permeable membrane is a membrane with pores sufficiently large to permit the passage of molecules of the solution, in this case water, but too small to permit the passage of dissolved solutes such as salts. As the system equilibrates, it results in a more concentrated solution on one side of the membrane and a pure water solution on the other side. The pressure exerted on the water molecules as they pass through the membrane is termed osmotic pressure, and the process does not stop until all molecules of the solvent have crossed the membrane or a pressure exerted by the solvent molecules on the other side equates with the osmotic pressure. This pressure can be in the form of water pressure as shown in Figure 2c or an externally applied pressure as in Figure 2d. Reverse osmosis relies on an externally applied pressure to stop and then reverse the process of osmosis, thereby using the system's semi-permeable membrane as a filter. Similarly, applying pressure to the side of the membrane featuring dissolved salts will speed up the process.

Figure 1: Osmosis

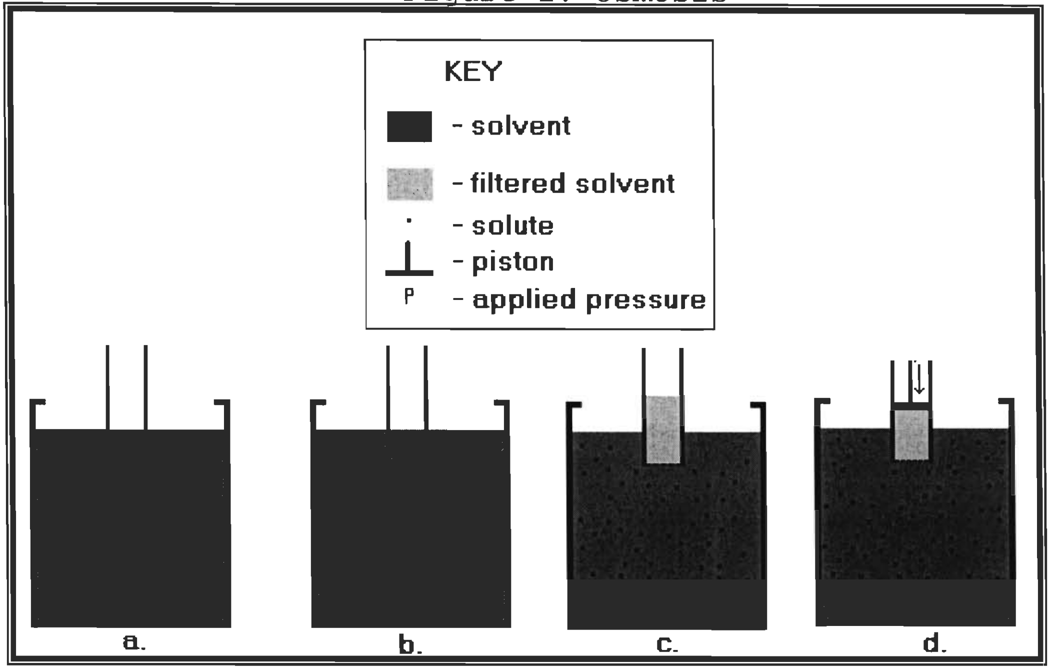

Figure 1 describes effects of osmosis on a tube and beaker system in 4 situations. A) No solutes present in beaker and no membrane on tube. Water level in tube is equal with level in beaker. B) A semi-permeable membrane is placed in on submerged end of tube, but no concentration of solutes is zero on both sides of membrane and no osmotic pressure exists. C) Solutes are present in beaker, osmotic pressure forces water level in tube to rise until water pressure in tube is equal to osmotic pressure of the system. D) Pressure in the form of a weighted piston is applied to tube, water level in tube drops until osmotic pressure equates to the sum of water pressure and pressure applied by piston, at which point a dynamic equilibrium is reached.

In reality the Yuma Reverse Osmosis Desalting Plant relies not on the principle of reverse osmosis, but rather uses a pressure of 362 pounds per square inch to force salinated water through a vast system of semi-permeable membranes.

The water enters the plant at an intake system where screens remove algae and large debris such as tree branches that would otherwise clog or damage the filtration system. The water is then treated with chlorine to kill microorganisms and stop the growth of algae.

Three-quarters of the water are then fed into the plant’s filtration system, which consists of 9000 cellulose acetate semi-permeable membranes packed into 1700 pressure vessels, each measuring 7 meters in length and 32 centimeters in diameter. It takes water 4.5 hours to flow through the filtration system, following which 90% of the original salt content of 3000 parts per million (ppm) are removed, resulting in a final salinity concentration of 300 ppm. The plant can produce 3200 liters of filtered water per second and has a final output of 275 million liters per day.

The desalted water is then mixed with untreated water in ratios that bring up the final salt content to a desired maximum allowed level to satisfy treaty agreements with Mexico. It then flows through a 360 yard lined canal back into the Colorado River.

A quarter of the water entering the plants intake system is left untreated and is used to concentrate the filtered salts and drive the energy recovery turbines at the plant. It is then released into the Gulf of California through the Santa Clara Marsh- the Cienega de Santa Clara, with a final salt concentration of approximately 10,000 ppm.

Drainage water from farmlands east of the Yuma Plant is bypassed around the plant at Morelos Dam, on the California-Mexico border and is carried to the Santa Clara Marsh in a 95-kilometer-long concrete-lined canal. The United States does not receive treaty credit for the untreated water because of the excess salinity levels and is forced to supplement the water loss with water from upstream storage reservoirs to make up the 1.5 million acre-feet of water allotted to Mexico under the treaty. (USBR)

The major setback to the system is the cost of the desalting process. The construction of the plant cost $290 million and the plant has an estimated yearly operational cost of $36 million. The USBR estimates the cost of filtered water at $308 per acre-foot before the blending with unfiltered water. Blending of unfiltered and filtered water reduces the price to $269 per acre-foot, a price that is 13% cheaper, but still astronomical when compared to water purchased by the City of Phoenix, Arizona from the Salt River Project, which supplies central Arizona with up to 1 million acre-feet of water per year, at $7 per acre-foot. (1) Due to the high operational costs and a recent increase in Colorado River water flow, the Yuma Desalting Plant functioned for only several months upon completion of construction in 1992 and has been standing idle since, with a skeletal cost of $5.1 million annually.

Another setback to operating the plant is the environmental effects of operation on the Santa Clara Marsh. The marsh was originally destroyed by water diversions to Mexico, but was revitalized when irrigation drainage got diverted into the marsh as a result of water too saline to meet international treaties. The marsh is a rich 14,000 acre biosphere that is home to several endangered species of fish and birds. The marsh currently receives over 100,000 acre-feet of water with an estimated salt content of 2,800 ppm. Operation of the Yuma Desalting Plant will desalt the water currently received by the river and divert it back into the Colorado River, resulting in a two-thirds drop in water received by the marsh, which will also experience a three time increase in salinity, resulting in an inability for the marsh to support its current size and wildlife populations.(Living Rivers)

Future:

The future of The Colorado River Basin is controversial and uncertain. As the salinity of the river increases, the agriculture industry in the basin will likely need to increase its consumption of water. Ironically, the industry that is most affected by the increased salinity levels is also the one most responsible for increase. Ideally, the increasing salinity of the river, in conjunction with practices that limit the amount of water dispersed to different regions, will likely force an equilibrium in which agriculture will become limited due to salinity levels and will thus cease to increase the consumption of water for irrigation. Realistically, however, the industry will likely continue to grow as technology evolves ways to increase crop density on given plot sizes. The best option for the river comes from educating farmers on more efficient and effective fertilizing and irrigating techniques. Several programs, such as the Colorado River Basin Salinity Control Program, authorized by the Department of Agriculture, do just this by providing farmers with technical and financial assistance in identifying salt sources and developing individual plans to help reduce salinity levels in Colorado river water, up- and downstream from irrigation points.

Use of manure instead of chemical fertilizers can also help ease the salt loading of the river. Millions of cattle graze in the basin, producing manure that is leeched into the soil. Increasing the percentage of manure produced in the region that is eventually used as fertilizer will lead to a decreased importation of chemical fertilizers into the ground. Fortunately, the use of manure as opposed to chemical fertilizers is on the rise. The nitrogen in chemical fertilizers comes primarily from natural gas, and soaring natural gas prices have steepened the prices of commercial fertilizers. The price of anhydrous ammonia, the most readily produced form of nitrogen for fertilizer use, has increased from $0.14/lb in 2000 to $0.25/lb. Michael Schmidt of the University of Minnesota reported that the price change will increase the price of fertilization from $20/acre to $35/acre in 2004. Manure fertilization, once relatively expensive at $30/acre, is thus starting to seem as a more profitable option for farmers, while the increased demand of manure will be a boon to the livestock industry manure conservation practices.(http://nationalhogfarmer.com/ar/farming_manure_value_rises/)