The High Plains Groundwater Demonstration Program

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Table of Contents

Table of Contents i
High Plains States Groundwater Demonstration Program 1
The Ogallala Aquifer 1
From Surface Water to Groundwater 3
A Depleting Water Supply 7
The High Plains States Ground Water Demonstration Program Act 11
Construction and Implementation, 1984-1999 16
Southeast Salt Lake County, Utah 20
Rillito Creek, Arizona 22
Blaine Gypsum, Oklahoma 23
Significance 25
Bibliography 28
Government Documents 28
Secondary Sources 29
Websites 29

High Plains States Groundwater Demonstration Program

Beginning in the 1980s the alarming rate of groundwater depletion gained national attention, along with the need to gather data and to test groundwater recharge technology. Congress called upon the Bureau of Reclamation to diverge from its usual program of developing surface water for agricultural, industrial, and municipal purposes and enter into the business of testing and developing groundwater resources. The High Plains States Groundwater Demonstration Program Act of 1983 gave Reclamation oversight of the program to test recharge technologies in a variety of geologic and hydrologic environments. From 1984 to 2000, working cooperatively with the Environmental Protection Agency (EPA), U.S. Geological Survey (USGS), U.S. Fish and Wildlife Service (FWS), Western States Water Council, National Academy of Sciences, and other federal, state, and water management organizations, Reclamation designed, constructed, and operated fourteen demonstration recharge projects in fourteen western states. Reclamation labeled the program the High Plains States Groundwater Recharge Demonstration Program because the intention was to find solutions to the rapid depletion of groundwater on the plains, and to the Ogallala Aquifer in particular. This was part and parcel of a growing awareness to the dangers of rapidly declining aquifer levels and a facet of a broader national program to reduce overdraft of the nation's groundwater resources.

The Ogallala Aquifer

Millions of years ago a vast inland sea, known as the Rocky Mountain Trough, stretched a thousand miles wide and three thousand miles long across North America. In the Jurassic Period the lake dried up, and then again the waters returned. This process occurred several times over millions of years, with each watery period laying down layers of sediment like sandstone and shale thousands of feet thick. When the waters receded wind and surface water eroded the sediment deposits. About 60 million years ago geologic uplifts began to create the Rocky Mountains, and in time glaciers and rivers from the mountains moved tons of material onto the Great Plains. The same flow of water created the aquifer, and the water sitting in the Ogallala Formation is ancient glacial water from the Rocky Mountains. Actually, the waters of the aquifer, like groundwater generally, is not sitting still but slowly shifting east about 12 inches per day toward the ocean.[1]

The Ogallala is one of the world's largest aquifers consisting of three billion acre feet of water spread out over 174,000 square miles over eight states. Two-thirds of the volume of water is in Nebraska where in some places the aquifer is more than 1,000 feet thick. In west Texas the aquifer is not nearly as deep. With an average depth of 500 feet, the aquifer is a huge underground body of water lying nearly stationary beneath the surface. At one time, when rainfall was plentiful on the high plains, the excess surface water recharged the aquifer. Now, in a semiarid climate where rainfall is minimal, the rate of recharge of the Ogallala is negligible at less than an inch per year.

That the Ogallala is replenished at all means that it is an unconfined aquifer in which water flows freely between the aquifer and the surface, as opposed to a confined aquifer wherein water is sandwiched between layers of impermeable rock. Still, the vast majority of the planet's freshwater supply—ninety-eight percent—is lodged under the

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[1] John Opie, *Ogallala: Water for a Dry Land* (Lincoln: University of Nebraska Press, 1993), 29-33; David E. Kromm, "Ogallala Aquifer," *Water Encyclopedia: Science and Issues*, available online at http://www.waterencyclopedia.com/Oc-Po/Ogallala-Aquifer.html.

soil within geologic formations of sand, soil, and rock. Groundwater is a precious resource across the globe but no less so than in the United States where half of all Americans use it for drinking water, and farmers, like those on the high plains, use it intensively to irrigate fields. Unfortunately, because the natural recharge of groundwater happens at a snail's pace, if at all, heavy pumping in even deep, large aquifers such as the Ogallala poses long-term threats to groundwater sustainability.[2]

From Surface Water to Groundwater

Early peoples on the high plains did not know the science behind groundwater or the difference between confined and unconfined aquifers or the rate of percolation in varying types of lithologic and hydraulic environments. In fact, even to the first Europeans who set foot on the plains in the sixteenth century, the idea that a large body of water lay dormant in the soil was unimaginable. On the plains, water was as scarce as it was plentiful in the East. Although tall grasses and fertile soils covered portions of the plains, the first Europeans noted the lack of trees and woody plants, presenting an alien and foreboding environment. The plains came to be known as a vast, dry, sterile, treeless expanse; Stephen Long's 1823 map of the region referred to it as the "Great Desert." In his report accompanying the map, Long stated, "I do not hesitate in giving the opinion, that it is almost wholly unfit for cultivation, and of course, uninhabitable by a people depending upon agriculture for their subsistence. Although tracts of fertile land considerably extensive are occasionally to be met with, yet the scarcity of wood and water, almost uniformly prevalent, will prove an insuperable obstacle in the way of settling the country."

[2] For information on groundwater, see U.S. Geological Survey, http://water.usgs.gov/ogw/; U.S. Environmental Protection Agency, http://www.epa.gov/waterscience/; The Groundwater Foundation, http://www.groundwater.org/index.html.

The arid nature of the country has made water a valued commodity. Due to the lack of water and wood for even modest-sized populations, many remained convinced that the plains were unfit for agriculture. Although the explorer and mapmaker John C. Frémont suggested that cattle and farmers could subsist on the plain's native grasses and soil, overland immigrants to the West famously passed over the plains with hardly a thought of lingering. Not entirely surprising, old notions of what the land could support shifted as the East's populations moved westward following the call of some boosters and agricultural enthusiasts touting the notion that "rain followed the plow"—meaning that planting trees and crops increased moisture and altered the climate. Some even claimed that empirical evidence proved the theory valid, but in fact the late 1870s and early 1880s were wet years and hardly typical climatic behavior on the plains. Nevertheless, farmers adapted to the hard realities of the plains by the application of dry farming methods and introduction of drought-resistant crops.[3]

How, then, did the plains become the nation's breadbasket—what one person has called "the last and best grain garden of the world"?[4] The answer lies in irrigation—specifically groundwater irrigation. Traditional irrigation is gravity diversion from surface water sources—streams, rivers, reservoirs, lakes—on to the land. In parts of the West, where canyons or depressions in the land conveniently held water, irrigators constructed dams to collect runoff for future use. On the flat plains, traditional irrigation in the form of big dams and extensive irrigation systems was more difficult because few good, deep dam sites existed. Still, landowners used what surface water was available to beneficial use. Homesteaders staked the best farmland adjacent to major rivers and

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[3] Howard R. Lamar, editor, *The New Encyclopedia of the American West* (New Haven, Connecticut: Yale University Press, 1998), 447-8.
[4] Opie, *Ogallala*, 94.

streams and bought up water rights for their fields. Yet problems with surface water on the plains are twofold: the water is in short supply and is not reliable. By the turn of the twentieth century, farmers faced perennial water shortages and overdrafts of the available water supply. While at that time nearly all farmers on the Great Plains used surface water, by the mid-twentieth century farmers had turned to dryland farming or dug wells to locate groundwater to supplement meager surface water resources to irrigate their crops. The success of these endeavors along with the discovery of vast aquifers roughly marked the end of plains farmer's dependence on surface water for agriculture, and they embraced a new reliance on a seemingly free and inexhaustible supply of groundwater.[5]

Initially, farmers mistakenly thought the supply was free and infinite. They tapped into it using a hand- or mechanically dug well without constraint or thought for where it came and to whom it belonged. People believed well into the twentieth century that the water flowed underground like a river, replenished by the snow melt of the Rockies or the Arctic.[6] It is now understood that the Ogallala Aquifer has no inlet, but farmers believed otherwise when they observed water flowing from the earth with relative ease and abundance. Unlike surface water, groundwater is not seen or much observed; it is hard enough to measure how much water is being pumped let alone the impact of pumping on the supply or its effect in other places. Farmers and policy makers had not the slightest idea whether the water belonged to the land or not.

The problem confronting farmers before 1930 was the mechanical means to pump the water from deep in the earth. In the nineteenth century, if no surface water was available, farmers and ranchers dug wells by hand. If they were lucky, they did not need

[5] Opie, *Ogallala*, 75.
[6] Ibid., 79.

to dig deep, or even dig at all. Fortunate landowners used groundwater from artesian springs, which due to pressure flowed freely to the surface, but most water users dug at least a hundred feet to reach the water level of the Ogallala. After 1930, improved drilling technologies enabled farmers to dig deeper wells, while better pumps allowed them to extract water at a faster rate. These technological advancements provided farmers with an easy method to apply water onto fields to grow grains, wheat, corn, sorghum, and a number of other crops. This was great boon to plains farmers because wells were relatively easy to dig, pumps easy to install, and with the flip of a switch water flowed to fields. In an unpredictable place, the pumps provide stability by supplying just the right amount of water with relative ease.[7]

Although pumps extracted water from the ground, more sophisticated technology and scientific study was needed to understand the hydrology of underground aquifers. As one scholar wrote in 1947, "There has always been more or less mystery connected with groundwater, probably for the reason that the early scientists and philosophers did not understand its origin or even what eventually became of it. Much superstition has been connected with well drilling, and many diverse opinions and theories have been developed which have been handed down from generation to generation."[8]

In the late nineteenth century, when little was known about groundwater, the U.S. Geological Survey and engineers in state departments began to conduct surveys studying the nation's groundwater supply, while devising modern well construction methods. At that time, groundwater use was minimal and random, not systematically developed. Pumping increased as technique and technology improved. By 1940 a quarter of the

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[7] Ibid., 6.
[8] E. W. Bennison, *Ground Water: Its Development, Uses and Conservation* (St. Paul, Minnesota: Edward E. Johnson, Inc., 1947), iv.

people served by public water supplies used groundwater from wells. Within just a few decades, the technology to pump groundwater had eclipsed any kind of political, legal, or hydrologic tools to control or manage it.[9]

Modern pumping technology and the slow rate of groundwater replenishment led some observers to speak out about the fate of the nation's water supply. When the historian Walter Webb wrote his seminal study *The Great Plains* (1931), he recognized the desire and need to pump from the aquifer but thought it dangerous when replenishing the slow-accumulating aquifer was "beyond the possibilities of even the most humid climate," let alone the plains.[10] In 1937 at the convention of the American Association of Water Well Drillers in New York, O. E. Meinzer, chief of the USGS's Ground Water Division, stated, "It is evident that we are confronted more than ever before with the practical problem of the quantity of water that can be withdrawn from wells, year after year, either by pumping or artesian flows." Clearly, heavy pumping of a finite resource was not sustainable without replenishing the groundwater stores. Mr. Meinzer did not object to drilling or allowing the water to "go to waste if it can be made to serve human welfare." Yet unlike surface water, whose use and recharge was plainly visible, hydrologists had no precise means of measuring how much water was taken out of the ground and how much was being recharged into it.[11]

A Depleting Water Supply

Extraction of groundwater accelerated after 1940, prompted by an increase in knowledge of the hydraulics of groundwater as well as improved methods of measuring and understanding the nature of groundwater. New drills dug wells much deeper than the

[9] Bennison, *Ground Water*, 5-6.
[10] Quote taken from Opie, *Ogallala*, 97-8.
[11] Bennison, *Ground Water*, 7-8.

old wells, while high capacity pumps delivered water to the surface at a rate of several cubic meters of water per minute. Moreover, water was cheap—practically free—and in some cases on the plains cost $15-20 for one acre foot of water, depending on the energy used to pump it.[12]

The reasons groundwater is attractive are the same reasons the nation's groundwater stores are in peril. The ease and low cost of extraction encourages overuse. Across the world, hand-cranked wells, tunnels that deliver water by gravity from upland aquifers, and motorized pumps lower water tables and, in some cases, entirely deplete freshwater aquifers. The entire water supply of a community is threatened when more water is extracted from the ground than replenished. As water levels fall, the harder it becomes for people without the requisite technology to extract water for subsistence. In some places, however, groundwater pumping causes serious environmental problems. When water is extracted from the ground, the land settles, causing a depression in the earth that can be costly, particularly in urban areas. In coastal areas depleted aquifers allow saline water to fill the void contaminating the fresh water supply.

Since groundwater is difficult to quantify or measure, matters of ownership and water rights become complicated. Historically, people either saw water usage as a right attached to the land or as common property belonging to all. In both cases the problems are pronounced. Water beneath the earth's surface cannot be rightly considered attached to any particular parcel of land because it is constantly shifting, similar to a slow moving river. The problem of viewing groundwater as a common good stems from the difficulty

[12] Department of Economic and Social Affairs, *Ground-Water Storage and Artificial Recharge*, Natural Resources/Water Series No. 2 (New York: United Nations, 1975), 1-2.

in measuring use, and some treat it like an inexhaustible commodity without responsibility for wise use.[13]

Another difficulty arises when existing water laws treat surface and groundwater as separate, unconnected entities. The oldest doctrine governing use of groundwater passed in England in 1843 held that a landowner could take water from the ground for his own use. Later in the nineteenth century the "reasonable use" doctrine stated that a person could use water under his land but limited that use to no more than was necessary to successfully produce crops. The notion of "correlative rights" was a refinement of the concept of reasonable use "by giving to each a just and fair proportion" in instances where the water supply was not sufficient for all parties. At best, such laws and principles governed the use of groundwater resources between two parties but did not control excessive pumping which may have depleted a specific water source. Nor did they fully account for the diversity of groundwater hydrology or the relationship between surface water and groundwater sources.[14]

The science and politics of solving the problem of depleted groundwater are not easily reconciled. The relationship of surface and groundwater supplies has not been well understood, and the political problems of implementing policy in line with the science are formidable. How, for instance, might governments monitor and regulate pumping when it is often localized and individualized?

In the United States, prior to the Second World War, a few states began to monitor well use and conserve groundwater. In 1935 the United States established the National Resources Committee with a special committee on groundwater, but

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[13] See Opie, *Ogallala*, 7

[14] Bennison, *Ground Water*, 458-9.

comprehensive regulations and water rights policy was far in the future.[15] Not until after the war, however, did water organizations, local municipalities, states, and the federal government address the problem head on. In some states, farmers and water users organized regional water-management districts or independent water associations to address the problem of groundwater. The Texas High Plains Underground Water Conservation District No. 1, organized in 1951, is one example. Later, they developed new irrigation methods and grew drought resistant crops to combat the problem. In the 1980s plains farmers began implementing groundwater conservation techniques, such as utilizing strict watering schedules and conserving runoff water in tail-water ponds. There was also a shift from traditional gravity irrigation to center-pivot irrigation and drip irrigation.[16]

Government policy, until recently, shied away from implementing strict controls on water use or from devising a national water policy that considered the interconnection of surface and groundwater supplies. On the Great Plains, government initiatives encouraged heavy use of the aquifer and subsidized farmers during times of drought. By the 1970s the government took steps to find ways to conserve water on the plains. In 1978, at the behest of Congress, the USGS began to develop the Regional Aquifer-System Analysis. At the same time Congress debated Reclamation's recharge demonstration program, it also passed a farm bill that subsidized farmers who retired their land from irrigation.[17]

[15] Ibid., 456.
[16] Opie, *Ogallala*, 13-14.
[17] Department of the Interior, Bureau of Reclamation, *High Plains States Groundwater Demonstration Program, Program Summary Report*, Part 1 and 2, June 2000, 2.1; Opie, *Ogallala*, 22-3.

Arizona is a good example of a state struggling with groundwater depletion that took active steps to correct the problem in the long term. Arizona's legislature passed the Groundwater Act of 1980; considered by many as a pioneering achievement in implementing legal codes to address the problem of groundwater depletion. The act created groundwater basins called Active Management Areas and Irrigation Non-Expansion Areas, set up rules for conservation of groundwater, and eventual elimination of overdraft by 2025. Although the law was a landmark in groundwater conservation designed to put the state on the path of sustainability, some observers argue that the act failed in its intended purpose. According to scholars at Arizona State University, "subsequent loopholes and evasions have gutted its original intent and taken the state off the path toward sustainability." This analysis was a common and cautionary tale throughout the arid West.[18]

The High Plains States Ground Water Demonstration Program Act

The idea of groundwater recharge is to take unappropriated surface water and divert it into aquifers where it can be stored. In the southern high plains plans were to somehow use storm water collected in depressions in the earth for this purpose. If researchers found a way to pump that water into the ground, it would save an estimated 2-6 million acre feet annually usually lost to evaporation. Water managers and scientists began to understand the benefits of recharge, not merely as a conservation method but as a means of water storage. Still, recharge is not a simple process—neither in a political nor hydraulic sense. Certainly by the late twentieth century much of the West's water

[18] Douglas E. Kupel, *Fuel for Growth: Water and Arizona's Urban Environment* (Tucson: University of Arizona Press, 2003), 176-7; Paul Hirt, Annie Gustafson, and Kelli L. Larson, "The Mirage in the Valley of the Sun," *Environmental History* (July 2008): 482-514, <http://www.historycooperative.org/journals/eh/13.3/hirt.html> (Accessed March 17, 2009).

had been appropriated if not over appropriated, making the amount of water available for recharge politically controversial and potentially expensive. Moreover, the process of returning water to the ground was not entirely straightforward, and no one had adequately tested every combination in terms of technique, geology, and hydrology.

The oldest form of groundwater conservation is sealing artesian wells, abandoned wells, or wells in which the casing has failed. An early method of groundwater recharge was water spreading—dating back at least to 1889 when the Denver Union Water Company tried the technique near the mouth of the South Platte River. Typically, the practice was to divert surface water to designated spreading basins where the water seeped into the soil, but the methods varied depending on available water supply and geologic and lithologic characteristics. Another early technique was using wells or pits to recharge the aquifer, but this practice was considerably less tested and reliable. The best early example of this was on Long Island in Nassua County, New York, where by 1937, 105 recharge wells had been put into operation.[19]

Recharge methods increased in popularity and use as groundwater mining reached alarming proportions in the last half of the twentieth century. In Kansas where groundwater mining of the Ogallala Aquifer was most severe, the USGS, in cooperation with the Kansas Water Resources Board, studied the method and potential for recharge in the Wet Walnut Creek valley in central Kansas. Initiated in 1968, the project's purposes were to develop methods to replenish the aquifer using storm runoff and provide data to plan for groundwater management. According to Keith S. Krause, executive director of the Kansas Water Resources Board, "the results have exceeded our most optimistic

[19] Bennison, *Ground Water*, 481-82, 489, 496; *Congressional Record*, June 20, 1983, 16386; *Congressional Record*, February 23, 1982, 2030.

expectations."[20] Interest in recharge accelerated as the problems of overdrafting became acute. The California Department of Water Resources produced a report in 1974,[21] and in Arizona the city of Phoenix began studies of its own to mitigate subsidence in urban areas caused by groundwater pumping. Arizona is a good example of a western state actively responding to the groundwater crisis and planning ahead for the future. In the 1980s, the state considered construction of a recharge project at Cave Creek Wash area to store Central Arizona Project water for future use. Later, in 1990, the state authorized demonstration projects for recharge that led to successful results in the Phoenix and Tucson areas.[22] Thus, the national recharge demonstration program authorized in 1984 and spearheaded by the Bureau of Reclamation should be understood in this larger context of dealing with the groundwater crisis in America.

In 1982 Nebraska Congressman Douglas Bereuter introduced legislation to establish a series of groundwater recharge demonstration projects in the high plains states (Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming). Nowhere was overdrafting more alarming than in this area, a region addicted to groundwater for irrigation. In some places groundwater mining reduced the water table as much as 200 feet and in certain places threatened to deplete it entirely by the year 2000.[23] Bereuter, an urban planner by training, worked with colleagues from other plains states on the Committee on Interior and Insular Affairs on this piece of legislation. He called the program "modest," designed only to "target those areas of the worst declines

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[20] Department of the Interior, U.S. Geological Survey, *Artificial Ground-Water Recharge, Wet Walnut Creek, Central Kansas*, Progress Report Number Two, Topeka, Kansas, January 1970, frontpiece, 1-2.
[21] State of California, Department of Water Resources, *Ground Water Storage of State Water Project Supplies: District Report*, June 1974.
[22] Kupel, *Fuel for Growth*, 195, 211-15.
[23] *Congressional Record*, April 28, 1982, 7940; *Program Summary Report*, 2.19-2.20.

and the best possibility for a successful recharge project." The bill provided for an eighteen-month planning stage and a five-year demonstration period, after which recommendations would be made to construct full-scale recharge sites where the concept proved feasible.[24]

In 1983, with an introduction by House representatives of H.R. 71, High Plains States Ground Water Demonstration Program Act of 1983 (Public Law 98-434) called for a recharge program that included the entire West, not simply the high plains. Although certainly the threat to the Ogallala was arguably the most pressing, the legislation acknowledged that groundwater depletion was a serious threat throughout the West. Moreover, widening the reach of the program allowed for testing recharge methods in diverse environments. As Congressman Hank Brown of Colorado stated, "The technical aspects of recharge have been studied, but tested on only a very limited basis. As a result, it is not known whether or not a technique shown to be successful in one region might also be successful in another."[25]

Architects of the legislation hoped to go beyond theoretical models and hypothetical solutions for what Bereuter called "concrete data" that would not only spur construction of efficient, cost-savings storage and conservation projects but also enable recharge technologies to be built onto existing water projects.[26]

Perhaps not surprisingly, Congress designed and justified the legislation principally on the basis of economic terms. Authors of the legislation warned of a depleted aquifer taking millions of acres of land out of production and having a devastating impact on industrial development and energy production on the plains. They

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[24] *Congressional Record*, April 28, 1982, 7940.
[25] *Congressional Record*, June 20, 1983, 16385-86.
[26] Ibid., 16387.

highlighted the impact on economies, not on ecosystems. Their concern was that as unchecked groundwater mining reduced irrigated agriculture—from 8 million acres in 1975 to 2.2 million in 2020, according to the General Accounting Office in 1977[27]—the breadbasket of the world would tailspin into social and economic depression. Proponents were also careful to note that the program was not pork barrel; that allowing the aquifers to decline would be tragic not merely on a local scale, but had national implications. At a time when the federal government was scaling back funding for new water projects, proponents pushed the program on grounds of cost sharing and inserted provision that states, local governments, and private sources match government funding by 20 percent.[28]

The bill passed the House and Senate after Congress agreed to several amendments: 1) no water could be drawn from the drainage basin of the Great Lakes, 2) the Department of the Interior and EPA would enter into a memorandum of understanding with regards to the impact on water quality, and 3) no project funds could be used related to the interstate transfer of water from Arkansas.[29] In Phase I, the act directed the secretary of the interior to make preliminary recommendations of projects to receive additional consideration. The sites for demonstration projects had to clear certain criteria: "a declining water table, an available surface water supply, and a high probability of physical, chemical, and economic feasibility for recharge of the ground-water reservoir." Site selection was just the beginning. The act directed the Bureau of Reclamation to design the water replacement works, determine how to operate them, and iron out the environmental and legal difficulties. During Phase II, Reclamation was to study cost effective measures, to allocate the cost of recharge to beneficiaries, and to

[27] Opie, *Ogallala*, 162.
[28] See *Congressional Record*, June 20, 1983, 16388.
[29] *Congressional Record—Daily Digest*, August 10, 1984, D 625.

design, construct, and monitor the recharge projects in consultation with the USGS, EPA, and other appropriate federal agencies.[30]

Construction and Implementation, 1984-1999

The irony in the groundwater recharge demonstration program was that, although the depletion of the Ogallala Aquifer directly raised the alarm and prompted the project, only two projects in Nebraska—York and Wood River—recharged water into the Ogallala. The 1983 legislation directed Reclamation to design, construct, and operate no fewer than twelve sites in the high plains states and no fewer than nine sites in the other western states. At first, the Bureau considered forty-one project sites, then in December 1987 narrowed the list to twenty-one for Phase II implementation.[31]

The lapse between phases I and II was marked by the introduction of legislation to elevate the groundwater recharge demonstration program to the national level. Not to be left out of the recharge program, Trent Lott from Mississippi introduced the National Groundwater Recharge Demonstration Program Act of 1988 as a "national pilot program for testing recharge techniques." In March 1988 Lott spoke before the House of Representatives of the need to test soil, geology, water quality, evaporation rates, and other variables "on an area-specific basis" in places like Mississippi, where according to Lott 93 percent of the population relies on groundwater and faces the real threat of saltwater intrusion along the Mississippi Gulf Coast. Lott pointed out that recent U.S. Geological Survey groundwater models along the Gulf Coast raised the alarm of the threat to freshwater aquifers. The problem was that in many areas like the Mississippi

[30] "High Plains States Ground-water Demonstration Program Act of 1983" (September 28, 1984), U.S. Department of the Interior, Bureau of Reclamation, *Federal Reclamation and Related Laws Annotated (Preliminary)*, Volume V of Five Volumes, 1983-1998, Donald L. Walker, editor (Denver, Colorado: Government Printing Office, 2001), 3424-3428.
[31] *Program Summary Report*, E2.

Gulf Coast where groundwater recharge using surplus surface water from high rainfall is a distinct possibility, no testing of recharge technology has been done.[32]

Congress did not pass the national groundwater recharge act, but the idea was important because like the 1983 act, it signaled a significant departure from traditional Bureau of Reclamation activities. Prior to the 1980s, Reclamation planned, designed, constructed, and administered surface water irrigation projects in the western states. Now, not only had Congress extended Reclamation's functions to groundwater management, but it considered broadening its oversight on a national scale. Lott believed the 1988 legislation was compatible with the changing focus of the Bureau's mission as a caretaker and management role of water resources.[33] Although Reclamation would not assume a national role in that area, the groundwater recharge program reflected a substantially diversified approach to water management.

In fiscal year 1989 Congress appropriated $3 million for initial construction of projects identified under Phase I site selection. At 1983 price levels, the expected cost of the program neared $20 million, but since the cost of environmental monitoring systems and protection features did not factor into this figure, the Department of the Interior prepared legislation to increase the cost ceiling to $31 million.[34] Each project fell under the jurisdiction of what was called a "project sponsor," usually a municipality or local water organization or agency responsible for implementation. The idea of a sponsor

[32] *Congressional Record*, March 23, 1988, 5090-1.
[33] Ibid., 5091.
[34] U.S. Department of the Interior, Bureau of Reclamation, *High Plains States Groundwater Demonstration Program 1989 Interim Report*, September 1989, 8.

stemmed, no doubt, from the line in the act directing Reclamation to find ways to allocate project costs. Reclamation and the EPA would provide oversight and review.[35]

As late as 1989 it was anticipated that twenty-one projects would participate in the groundwater demonstration program. A year earlier sponsors of three projects—Adams County Project in Nebraska, the Big Bend Project in Kansas, and the Alamagordo Project in New Mexico—voluntarily withdrew from the program when it became clear that local municipalities or water districts were unable to meet the cost-sharing requirements. Participating federal agencies scrambled to select replacement projects, and by mid-1989 Reclamation recommended inclusion of the Wood River, Nebraska, Woodward, Oklahoma, and Texas High Plains, Texas projects for participation in the High Plains States Groundwater Demonstration Project. Reclamation deferred other projects selected for Phase II pending additional appropriations or further determinations to drop them entirely from the list. The number of projects that received original construction appropriations was thirteen.[36]

Scattered across the seventeen western states (except California, New Mexico, North Dakota, and Wyoming), the projects tested recharge technologies and methods in shallow unconfined, deep confined, shallow confined, and shallow to moderate depth karst. The most common method was direct well injection using active pumping (Denver Basin, Colorado; Southwest District, Idaho; Washoe, Nevada; Hermiston, Oregon; Huron, South Dakota; Hueco Bolson, Texas; Southeast Salt Lake, Utah; Highline, Washington), but methods also included natural instream recharge (Rillito Creek, Arizona), passive infiltration ponds (Southwest District, Idaho), surface infiltration

[35] *Program Summary Report*, E2, 2.3.
[36] *High Plains States Groundwater Demonstration Program 1989 Interim Report*, 6-7.

(Equus Beds, Kansas; Wood River and York, Nebraska; Blaine Gypsum, Oklahoma), gravity-feed passive injection wells (Equus Beds, Blaine Gypsum), agricultural practices to enhance surface infiltration (Turner-Hogeland, Montana), and inter-aquifer transfer (Hermiston).[37]

On a cost and technological scale, surface infiltration is least intensive because it only entails water percolating into the ground where it settles in unconfined aquifers. In this case, the water is hard to monitor and has a higher evapotranspiration rate than do other forms of aquifer recharge. The most expensive, complex method is direct well injection that pumps water directly into the aquifer, but because the water is recharged into a specific location it is simple to track and highly successful.[38]

The original authorizing legislation directed Reclamation to determine the "economic feasibility of and the legal authority for utilizing ground-water recharge." After the first year, project managers concluded that the cost of recharge was higher than anticipated. The original designs and cost allocations paid little attention to maintaining water quality in contaminated aquifers, but it quickly became apparent that it did no good to restore water levels to their former levels without ensuring that the water quality was first-rate. Reclamation worked with the EPA on a groundwater quality monitoring program.[39]

Moreover, as the co-coordinating agency, Reclamation sponsored meetings every year at one of the recharge sites where representatives from federal, state, and local agencies and organizations, and the public discussed issues related to the demonstration

[37] *Program Summary Report*, E4.
[38] *Program Summary Report*, E7; Frederick Bloetscher, Albert Muniz, and Gerhardt M. Witt, *Groundwater Injection: Modeling, Risks, and Regulations* (New York: McGraw-Hill, 2005), 5-7.
[39] *High Plains States Groundwater Demonstration Program: 1989 Interim Report*, E1.

recharge program. Part of Reclamation's oversight responsibilities, in collaboration with the EPA or other organizations, was to produce annual status reports, summary reports of each project, and other groundwater recharge studies.[40]

Some projects had been delayed by drought and required additional funding. Congress responded by passing the Reclamation Projects Authorization and Adjustment Act of 1992 (P.L. 102-575). The act raised the budget to $31 million at October 1990 price levels, permitted the secretary to recommend additional demonstration projects, and made minor adjustments.[41] The Office of the Inspector General concluded in 1993 that no new projects were necessary to accomplish the stated objectives of the recharge demonstration program. However, Congress later passed legislation appropriating funds for an additional project, Equus Beds in Kansas, bringing the total number to fourteen.[42]

Below, three projects are summarized to provide a sample of demonstration projects' operation, challenges, and outcomes. Each project represents varying methods of recharge and diverse geologic and lithologic conditions tested by recharge technology.

Southeast Salt Lake County, Utah

The Salt Lake County Water Conservancy District (SLCWCD), a municipal water provider to 400,000 people, sponsored and headed construction of the Southeast Salt Lake County project. Located on a high bench along the Wasatch Front, the project pumped water into an unconfined aquifer at the site of prehistoric Lake Bonneville and a highly populated residential area. Using injection wells, the project injected 3,200 acre feet of water annually into the east bench of Salt Lake Valley. The Salt Lake Aqueduct

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[40] *Program Summary Report*, 2.6-2.7.
[41] "Reclamation Projects Authorization and Adjustment Act of 1992" (October 30, 1992), USDOI, BR, *Federal Reclamation and Related Laws Annotated (Preliminary)*, 3913.
[42] *Program Summary Report*, 2.4.

carried water from Deer Creek Reservoir to the injection site during fall and winter months, to stored water for municipal uses during the dry, hot summer months.

Reclamation anticipated a one-year construction period for the injection, recovery, and monitoring wells and filtration treatment facility at a cost of $3,295,800 at 1986 price levels. However, the project ran into unexpected issues that tabled the project for a short period. The first was related to water quality. According to standards set by the Utah State Water Pollution Control Board, the quality of water injected into an aquifer must not exceed that of the aquifer by more than ten percent. Although the water quality from Deer Creek is high, the total dissolved solids exceeded those in the aquifer by more than ten percent, and the project could not proceed without a waiver, modified standards, or a new desalting plant. To add to this, in January 1989 the EPA released water quality standards pertaining to the groundwater demonstration program that stipulated that water injected into aquifers could not exceed National Primary Drinking Water standards—another potentially costly obstacle confronting the Southeast Salt Lake County project.[43]

The district solved the quality problem by treating the water at an inline filtration treatment facility downstream of the Little Cottonwood Water Treatment Plant. At the conclusion of the monitoring program, the district announced its intention to convert the demonstration program to aquifer storage and recharge project of eighteen injection wells. Meanwhile, the state of Utah had developed recharge laws and a permit system that made a full-scale recharge program possible.[44]

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[43] *High Plains States Groundwater Demonstration Program 1989 Interim Report*, 50-53.
[44] Salt Lake County Water Conservancy District and U.S. Department of the Interior, Bureau of Reclamation, "High Plains Groundwater Demonstration Program, Southeast Salt Lake County Artificial Groundwater Recharge Demonstration Project Summary," February 1996.

Rillito Creek, Arizona

Whereas the Southeast Salt Lake County project is an example of "artificial" recharge—with transported water from another watershed, no less—Rillito Creek aimed to augment natural instream groundwater recharge by impounding storm runoff. In other words, to capture storm runoff water and combine it with the stream flow that naturally recharges the aquifer. Water managers and hydrologists hoped this would prove an effective, low-impact method of recharge in a state with few good remaining dam sites and unallocated surface water available. Still, to make this project happen the local sponsor, the Pima County Department of Transportation and Flood Control District, had to resolve the question of downstream water rights that might be affected by the loss of flood runoff.

The potential for recharge on Rillito Creek had been known since 1959 when the University of Arizona and the U.S. Geological Survey prepared preliminary surveys. However, no progress on that front came until the 1980s when Reclamation folded recharge at Rillito into its groundwater demonstration plan. Local water interests formed the Rillito Project Management Committee (RPMC) and a steering committee to move the project forward, and they began the lengthy process of collecting data and monitoring water flows and quality. The effort required the coordination of the district, Reclamation, the Environmental Protection Agency, and the U.S. Geological Survey. The plan was to build impoundment gates to capture excess water from Rillito Creek and Alamo Wash.[45]

Not only did the monitoring and data collecting take longer than expected, but the project got caught up in legal, technical, and institutional snares. For instance, there were disputes over surface water rights. Not until 1994 did the state of Arizona issue surface-

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[45] *High Plains States Groundwater Demonstration Program 1989 Interim Report*, 10-11.

water permits to the district, but by that time economic and technical challenges seemed to pose serious obstacles to project construction. In 1995 the district indefinitely tabled the project for the stated reasons of "limited aquifer storage capacity, lack of economic benefits, staffing needs and development costs."

Although Reclamation dropped the Rillito Creek project from the demonstration program, the preliminary work and data proved helpful to water organizations in other arid and semiarid environments attempting similar recharge. Even at Rillito Creek, recharge of Tucson's central well field using Central Arizona Project water is a distinct possibility in the future. A tangible product of the project is expansion in the Rillito watershed of the existing Automated Local Evaluation in Real Time (ALERT) system, a network of gauges that provide in "real time" essential weather data. Thus, although the expected full-scale recharge development never came to fruition, the project—hailed as "the first of its kind in Arizona to contemplate direct impoundment and infiltration of storm water within an unregulated, ephemeral stream system"—served a decidedly useful purpose.[46]

Blaine Gypsum, Oklahoma

For decades farmers operating north of the Red River near the Texas-Oklahoma line pumped heavily from the Blaine Aquifer. In 1968, as pumping and drought steadily lowered the water table, farmers in Harmon County formed the Southwest Water and Soil Conservation District and began to build recharge wells and diversions to raise water levels. By the time Reclamation established the High Plains States Groundwater Demonstration Program, farmers at Blaine Gypsum had been involved in aquifer

[46] Pima County Department of Transportation and Flood Control District and EPA, *Final Report, Rillito Recharge Project*, June 1996, v, vii.

recharge for nearly two decades. The task of the federal recharge demonstration program at Blaine Gypsum was to determine the feasibility of recharging surface runoff into the aquifer using gravity-flow wells.

The first steps were to monitor water quality and to sign a cooperative agreement with the Oklahoma Water Resources Board (OWRB), the project's sponsor. Then, the OWRB issued, after a five-month technical delay, a contract for construction of the recharge wells and monitoring wells. The contract firm located sites for wells in places where water was able to penetrate the aquifer and seep into cavernous spaces for storage. Actual recharge began on June 1993 and monitoring began several months later in August. The OWRB requested a two-year project extension to collect more post-recharge data, and Reclamation approved the request with a completion date of October 2, 1997. Working with the EPA, the Fish and Wildlife Service (FWS), and other federal agencies, the board took care to mitigate impacts to wildlife, the environment, and cultural resources on the site. The tragic bombing of the Murrah Federal Building in Oklahoma City on April 19, 1995, destroyed the OWRB's main office, but all data related to the Blaine Gypsum demonstration project had been saved off site.[47]

At the end of the project's life, OWRB turned over operation and maintenance to the district with the expectation that the recharge wells would continue to be used. By all accounts, the demonstration project proved gravity wells to be highly effective; they pumped 1,056 acre feet back into the aquifer and in the short term increased groundwater quality.[48]

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[47] Oklahoma Water Resources Board and U.S. Department of the Interior, Bureau of Reclamation, *Blaine Gypsum Groundwater Recharge Demonstration Project Final Report*, October 1997, S1-S2, 1-6, 1-7.
[48] "OWRB Blaine Artificial Recharge Project is successful," *U.S. Water News Online*, May 1998, http://www.uswaternews.com/archives/arcconserv/8owrbla5.html.

Significance

When Congress introduced the groundwater demonstration program, proponents assigned it special significance. The importance stemmed from divergence from the traditional emphasis on developing surface water supplies for irrigation in the West. As Nebraska Senator J. James Exon stated, the program "would bring the Bureau of Reclamation into current thinking with the water community regarding the importance of ground water recharge." Project supporters hoped that the program would be the impetus to rewrite federal water policy "to recognize the important interrelationship of ground water to the hydrologic cycle."[49]

To that end the program contributed new data and information on feasibility, economic benefits, and costs of recharge in a variety of environments. The costs, however, were not evenly distributed. Recharge technology and methods came at a high cost, and the smaller the project the less economically feasible they were without some measure of cost sharing. Municipalities with the economic resources to monitor water quality were more successful than irrigation interests that employed simpler cost-effective recharge methods.

Reclamation positively assessed the demonstration projects as "examples for future recharge efforts." States aided in formulating groundwater recharge, tested water rights issues, addressed legal problems, and showed the economic feasibility of aquifer recharge. In 2000 Reclamation proclaimed, "The program successfully demonstrated the technical efficacy, economic efficiency, and financial feasibility of artificially enhancing recharge across a broad spectrum of political, geographic, and institutional boundaries,

[49] *Congressional Record*, April 7, 1983, 7789.

under circumstances where recharge technology was previously unused or rarely applied."

Aquifer recharge programs are a good example of federal-local partnerships and cost-sharing ventures that result in long-term investments. Six of the projects were converted into "full-scale recharge facilities or paved the way for expanded recharge plans"; the others presented possibility of further development.[50] All served the purpose of suggesting "important pitfalls and ways problems might be avoided in future planning." The programs convinced local water users not only how recharge technology worked but that it was a viable economic option for farmers and municipalities looking to increase their water supply and stem the tide of groundwater depletion. From a policymaking perspective, the projects tested water rights issues and legal questions of recharge. As a seed project, it convinced lawmakers and water users that recharge technology worked in a range of geologic and hydrologic environments and ought to be more widely implemented.[51]

Where to go from here? Thanks in large part to the demonstration program, there is evidence that recharge is a viable method of replenishing existing supplies, as well as storing water. As one water expert writes, "Storing water underground has several advantages over storage in surface reservoirs; in particular, it does not evaporate and it is protected from contamination by human and animal wastes."[52] Policy makers will no doubt continue to promote recharge and provide technical assistance and coordination to local water organizations interested in groundwater conservation and responsible

[50] *Program Summary Report*, E6-E7.
[51] Ibid., E6.
[52] Patrick McCully, *Silenced Rivers: The Ecology and Politics of Large Dams* (Atlantic Highlands, New Jersey: Zed Books, 1996), 199-200.

development. Protecting our aquifers and groundwater resources should be a matter of national, urgent concern.[53]

With the last of the projects coming to conclusion in 2000, Reclamation no longer oversees the recharge demonstration program or has much of a role in groundwater management, either on a regional or a national scale. However, the challenges of a declining water table and contaminated groundwater will push policymakers to integrate groundwater and surface water in their management plans. Reclamation may yet play a role in those endeavors.

[53] Specific actions are listed in *Program Summary Report*, E11.

Bibliography

Government Documents

Department of Economic and Social Affairs. *Ground-water Storage and Artificial Recharge*. Natural Resources/Water Series No. 2. New York: United Nations, 1975.

Oklahoma Water Resources Board and U.S. Department of the Interior, Bureau of Reclamation. *Blaine Gypsum Groundwater Recharge Demonstration Project Final Report*. October 1997.

Pima County Department of Transportation and Flood Control District and EPA. *Rillito Recharge Project Final Report*. June 1996.

Salt Lake County Water Conservancy District and U.S. Department of the Interior, Bureau of Reclamation, "High Plains Groundwater Demonstration Program, Southeast Salt Lake County Artificial Groundwater Recharge Demonstration Project Summary," February 1996.

State of California, Department of Water Resources. *Ground Water Storage of State Water Project Supplies: District Report*. June 1974.

United States Congress. *Congressional Record*. 1982-84. Washington, D.C.

United States Department of the Interior, Bureau of Reclamation. *Federal Reclamation and Related Laws Annotated (Preliminary)*. Volume V of Five Volumes, 1983-1998. Donald L. Walker, Editor. Denver, Colorado: Government Printing Office, 2001.

United States Department of the Interior, Bureau of Reclamation. *High Plains States Groundwater Demonstration Program: 1989 Interim Report*. September 1989.

United States Department of the Interior, Bureau of Reclamation. *High Plains States Groundwater Demonstration Program, Program Summary Report*. June 2000.

United States Department of the Interior, Bureau of Reclamation, and Oklahoma Water Resources Board. *Blaine Gypsum Groundwater Recharge Demonstration Project Final Report*. October 1997.

United States Department of the Interior, U.S. Geological Survey. *Artificial Ground-Water Recharge, Wet Walnut Creek, Central Kansas*. Progress Report Number Two. Topeka, Kansas, January 1970.

Secondary Sources

Asano, Takashi, editor. *Artificial Recharge of Groundwater*. Boston: Butterworth Publishers, 1985.

Bennison, E. W. *Ground Water: Its Development, Uses and Conservation*. St. Paul, Minnesota: Edward E. Johnson, Inc., 1947.

Bloetscher, Frederick, Albert Muniz, and Gerhardt M. Witt. *Groundwater Injection: Modeling, Risks, and Regulations*. New York: McGraw-Hill, 2005.

Hirt, Paul, Annie Gustafson, and Kelli L. Larson. "The Mirage in the Valley of the Sun." *Environmental History* (July 2008): 482-514. <http://www.historycooperative.org/journals/eh/13.3/hirt.html>

Kupel, Douglas E. *Fuel for Growth: Water and Arizona's Urban Environment*. Tucson: University of Arizona Press, 2003.

Lamar, Howard R., editor. *The New Encyclopedia of the American West*. New Haven, Connecticut: Yale University Press, 1998.

McCully, Patrick. *Silenced Rivers: The Ecology and Politics of Large Dams*. Atlantic Highlands, New Jersey: Zed Books, 1996.

Opie, John. *Ogallala: Water for a Dry Land*. Lincoln: University of Nebraska Press, 1993.

Websites

The Groundwater Foundation. http://www.groundwater.org/index.html.

U.S. Environmental Protection Agency. http://www.epa.gov/waterscience/.

U.S. Geological Survey. http://water.usgs.gov/ogw/.

U.S. Water News Online. http://www.uswaternews.com/archives/arcconserv/8owrbla5.html.

Water Encyclopedia: Science and Issues. Available online at http://www.waterencyclopedia.com/Oc-Po/Ogallala-Aquifer.html