CHAPTER TWO

A History of Irrigation Technology Used to Exploit the Ogallala Aquifer

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In James Michener's historical novel Texas, cotton farmer Sherwood Cobb decides to sell his large farm in the rich blackland prairie soil near Waxahachie and to move his family west to the High Plains. There he plans to buy thousands of acres of flat land, to sink irrigation wells, and, like his southern-plantation forebears, to raise cotton. The fortunes of his ancestors had been produced by chattel slaves, but Cobb would seek his fortune through another type of exploitation: by pumping (mining is perhaps more descriptive of the effect) groundwater from one of the world's vast aquifers. Cobb oversimplified the phenomenon as he enthusiastically explained it to his wife, Mary Nell: "Think of it as a vast underground lake. Bigger than most European countries. Dig deep and you invariably find water. It's called the Ogallala Aquifer, after this little town in Nebraska where it was discovered. Fingers probe out everywhere to collect immense runoffs, and the aquifer delivers it right to our farm" (Michener 1985, 969). Cobb obviously knew nothing of the fossil origins or of the limited recharge capacity of the Ogallala, but his attitude was common among early irrigators, who viewed the thick groundwater formation as an inexhaustible albeit reluctant goose awaiting only the technology capable of extracting the golden egg (Green 1973, 165-69).

When farmers first began to tap the Ogallala during the droughts of the late nineteenth century, the only technology available was the American-style windmill first patented by a New Englander named Daniel Halladay in 1854. The demand later in the century for these "wind engines" on the newly settled Great Plains was satisfied by scores of windmill-manufacturing companies and their salesmen (Baker 1985). By the 1890s, windmills were being used in conjunction with small earthen reservoirs by farmers desperate to irrigate a few acres of truck farms, orchards, or both. Some farmers even resorted to building their own "jumbo" or "battle-ax" windmills. Dr. W. J. Workman of western Kansas claimed in 1895 that he had constructed the largest jumbo ever built for
irrigation. Shaped like the horizontal paddle wheel on the stern of a steamboat, Workman's mill was 21 feet in diameter. An observer in 1897 noted that homemade mills were scattered throughout the Platte River valley of Nebraska (Sageser 1967, 107-18; Green 1973, 40--42).

One of the greatest advantages of the windmill was its cheapness. At the turn of the century many models sold for under $100 (not including the cost of drilling or digging the well and erecting a tower). Jumbos and battle-axes could be built for only a few dollars, especially when constructed on the farm (Green 1973, 41; Baker 1985, 76, 260-61). Windmill irrigation, however, had three important drawbacks: Windmills of that period were designed primarily for shallow depths of less than 80 feet; the machines could produce enough water for only a few acres; and the wind was not always a dependable source of energy, especially during the heat of summer when water was most needed. One farmer complained, "I know that Kansas had the reputation of being a windy state, but I have found, when it comes to making use of the wind, it is not there" (Longstreth 1895, 370).

Machines capable of lifting the water to the surface in quantities large enough to satisfy the thirst of Great Plains farmers for extensive commercial irrigation did not appear on the scene until about the turn of the century. The initial step in developing this technology occurred in 1875, when an improved centrifugal pump with diffusion vanes surrounding the impeller was patented in England. With this pump, water was sucked into the center of a circular chamber encasing the impeller and discharged through a pipe at the edge of the chamber by centrifugal force. The centrifugal pump, depending upon its size, could deliver large volumes of water, hundreds of gallons or more per minute. A large 10-inch pump (the measurement refers to the diameter of the discharge pipe) could pull 2,000 gallons per minute from a thick aquifer. Unlike the windmill's much smaller piston pump, which required a well of only a few inches in diameter, the centrifugal pump had to be set in a hand-dug pit not more than 20 feet or so above the water level of the well.

By 1900 two types of centrifugal pumps were in use—the horizontal and the vertical. The horizontal, named for its horizontal impeller-shaft, was used in shallower wells. The power was supplied either by an electric motor in the pit joined directly to the pump or by an internal combustion or steam engine at the surface connected to the impeller-shaft by a long, wide belt. An inclined trench had to be dug from the engine to the pump in order to accommodate the belt. The vertical centrifugal pump, usually set below the water level, was used for deeper wells, those below 25 feet. It had a long, vertical shaft aligned with shaft Bearings at various elevations within a wooden framework that reached to the surface. The most serious problem facing irrigators using the vertical pump was
the difficulty of perfectly aligning the shaft to protect the life of the bearings.

Irrigators were operating the early centrifugal pumps in a number of areas of the American West before 1900. In 1885 a centrifugal pump powered by a steam engine was in use near Eaton, Colorado, and Kansas farmers had the pumps by 1896 in the area of Garden City. By the turn of the century, centrifugal pumps could be found in the Sacramento Valley of California and in the valleys of Arizona (Green 1973, 44--47).

These early pumps were suited only for relatively shallow groundwater areas such as river valleys, however. Exploitation of the Ogallala required a pump that could be set in deep-drilled wells. The need for such a "pitless pump" was apparent in the California fruit and vegetable industry and in the Gulf Coast rice belt. Inventive minds in both regions at the turn of the century were independently at work, designing a large volume, deep-well pump.

As early as 1897, P. K. Wood of Los Angeles invented an inefficient screw pump consisting of propeller-like impellers within a pipe. In 1901 Byron Jackson of San Francisco built a deep-well, vertical centrifugal pump with its shaft prealigned in a tubular housing for the Pabst Brewing Company of Milwaukee. Power was supplied to the Jackson pump by an electric motor. Elwood Mead, later head of the Bureau of Reclamation, worked as consulting engineer on the project. Jackson, however, did not put his pump into production for several years.

Installation in deep wells of the kind of large volume pump designed by Byron Jackson required a different technology for drilling wells. The most common drilling method at the time, and probably still the most common for boring shallow, low-production water wells, was the "spudder," which literally punched a small-diameter hole in the ground by raising and dropping a steel bit. A rig capable of drilling a hole with a large diameter was needed for the new type of pump.

LAYNE'S "PITLESS" PUMP

The first inventor to put a "pitless" pump into production was a well-driller named Mahlon E. Layne. As early as 1886 Layne was drilling large-diameter wells in South Dakota, using augurs of 18 to 36 inches in diameter turned by a horse walking in a circle. His wells were designed for his patented well screen, placed at the bottom of wells plagued by fine sand. Layne's screen allowed the fine sand to pass through the perforations while gradually packing coarse gravel around the outside. This process would eventually keep the fine sand, now blocked by the gravel,
out of the well. For more than a decade Layne drilled wells for municipalities and railroads as well as for farmers in South Dakota, Nebraska, Minnesota, Wisconsin, and Iowa.

Layne continued to improve his rigs. Eventually six horses were required to turn his augur. In 1896 Layne built a rotary drill, similar to the rigs then being used in the Louisiana oil fields, and bought his first steam engine to furnish the power. When the vast Spindletop oil boom erupted east of Houston, Layne moved to Beaumont, Texas, hoping to use his screen for petroleum production. After only limited success in the oil fields, Layne and a young engineer named O. P. Woodburn turned to the nearby rice fields of the Gulf Coast. In 1902 the two men dug four pit-wells for a rice planter near Pierce, Texas. The pits were 8 to 10 feet square and 30 to 40 feet deep. At the bottom of each pit Layne and Woodburn then drilled wells, some 16 to 24 inches in diameter and approximately 100 feet deep, to draw upon the deeper strata of water. They cased the well as they drilled and installed a Layne Keystone Screen at the bottom (Green 1973, 49-50).

The drillers installed horizontal centrifugal pumps in three of the wells and a vertical centrifugal pump in the deepest well. All were powered by Fairbanks-Morse internal-combustion engines. Layne used rope as belting. The rope fit into grooved pulleys and extended from the oil-burning engines over idlers and down into the pits. Fifty-pound iron weights, dangling at the top of the pits, maintained the tension on the ropes. In later life, O. P. Woodburn recalled the nightmare of servicing those pumps: "Imagine getting down into the pit to oil the pump with the mess of rope running at the velocity of the outside diameter of the 54" fly wheel with 6 or 8 50# [pound] weights dancing on the tightener above your head. BAD DREAMS" (Green 1973, 51).

According to Woodburn, during summer 1902 when Layne and he were crawling out of those dangerous pits, Layne "got me off to the side of a building, sketched a pit on the wall with a pump at the bottom and shaft running to the top." The shaft was prealigned, enclosed in a pipe, and flanged onto the pump. The pump was to be installed in a large diameter steel casing set in a drilled well. Bearings would be lubricated by oilers at the surface, and the pump could also be raised or lowered from there. In 1903 Layne constructed his first crude pitless pump and installed it in a rice field near El Campo.

In 1904 Mahlon E. Layne formed a partnership with Woodburn and a salesman named P. D. Bowler. Two years later Layne patented the pump, and in 1907 he created the Layne and Bowler Company with its headquarters at Houston. The company did a booming business in the rice fields and at times could not keep up with the demand for the pump (Green 1973, 51-52). A Texas planter, one R. D. Ratliff of Ganado, put his en-
thusiasm for the pump to verse in 1908 when he wrote to Layne and Bowler:

That old fashion Pump!
   That old wooden pit,
When I dream of them now
   I most have a fit.

But then in my dreams,
   I realize at last
That the old Pumping outfit
   is a thing of the past.

My soul fills with joy
   And my heart gives a jump
When I remember with pleasure
   My "Layne [steel] Pit and Pump." (Green 1973, 52)

The pitless pump appeared to answer many an irrigator's prayers, but it also required a suitable power plant before it could be used to exploit the Ogallala Aquifer. Although steam engines were used to power some pumps in California, Arizona, and other parts of the West, one engineer

Boosterism was important when European settlement for farming began and remains so today. Seminole, Texas.
concluded after experiments in Arizona: "It will be seen that the expense of raising water by steam power is very great indeed, and that as a general proposition such water is too costly for constant use in ordinary farming operations" (Mead 1901, 66, 69).

NEW POWER SOURCES

Electric power, still in its infancy, held some promise. In a few areas near municipalities, where pump irrigation was concentrated, power companies actively solicited farmers to link electric motors to their pumps. In a few instances, electrical generating plants were built for the specific purpose of supplying power for irrigation plants. For example, the United States Sugar and Land Company used a central power plant near Garden City, Kansas, to supply energy to fourteen pumps in the Arkansas valley in 1909. That same year a group of farmers in the vicinity of Portales, New Mexico, formed an irrigation cooperative and contracted with the Westinghouse Company to construct a central power plant and to run electrical distributing lines to their wells. As collateral, Westinghouse held mortgages on the farmland. Neither project enjoyed success because the cost of electrical generation exceeded reasonable profits made on crops.

In the early years of European settlement, the High Plains was primarily a cattle area, with the animals grazing the nutritious native grasses. Although ranching continues, most animals today are confined in large feedyards. Gray County, Kansas.
The United States Sugar and Land Company project simply faded away. The Portales fiasco led to bankruptcy for the New Mexico farmers, and the Westinghouse power plant was sold to the city of Tulsa, Oklahoma (Green 1973, 53-55; Sorensen 1968, 88; Green 1990, 37-39).

By 1910 the internal-combustion engine appeared to be the cheapest power source for irrigation pumping plants. A German inventor named Nikolaus August Otto and an American, George Brayton, working independently, invented the first successful four-cycle internal-combustion engines in 1876. Otto's engine was powered by illuminating gas, but Brayton's engine, exhibited at the Centennial Exposition in Philadelphia, burned gasoline. Relatively expensive, gasoline at that time was used primarily as a cleaning agent and as a solvent.

Adapting the internal-combustion engine to a cheaper fuel occurred in 1890, when the English engineer Herbert Ackroyd-Stuart invented the low-compression oil-burning engine. Hornsby and Company of England first marketed the Hornsby-Ackroyd in 1894, and an American company was licensed to manufacture the engine the following year. Within a few years such companies as Primm, Charter, Bessemer, Van Sevrein, Fairbanks-Morse, Herr, and others were manufacturing their own oil-burning engines and marketing them throughout the nation.

The oil-burning engine had two desirable features: a simple design and cheap fuel. Most of the engines had only one large cylinder, with horsepower ranging from 5 to 70. There was no electrical system to bother with. The fuel was ignited by a "hot bulb" or "hot plug" in the head of the cylinder that in turn reheated the bulb or plug for the next ignition. Initially, the engine was started by heating the bulb or plug with an alcohol or gasoline torch. The operator then pushed the cylinder forward either by rotating the flywheel by hand or by opening a valve to a compressed-air tank that forced air into the cylinder head until the oil was injected. When the fuel splashed against a hot piece of metal (the "spoon" or "lip") extending into the cylinder head from the "hot bulb," it vaporized into gas, which was ignited by the bulb (Green 1973, 55-76). This early irrigation unit could be identified from a distance by the squat derrick, the small, frame building enclosing the engine that abutted onto the derrick, the loud arrhythmic pop-chug-chug-chug-pop of the engine, and the blue smoke belching from the vertical exhaust with each ignition. Some engines even blew an occasional smoke ring into the atmosphere.

By the outbreak of World War I, several hundred pumping plants were sucking from the Ogallala across the southern High Plains. Most were in the so-called "shallow water belt" stretching in a rough triangle from Hereford to Lubbock, Texas, to Portales, New Mexico. Western Kansas, Scott County in particular, also boasted a few of the pumping plants. D. L. McDonald drilled the first wells on the Texas Plains in 1909
The manufacturing sectors of the regional economy largely provide inputs for agriculture or process primary commodities. Above is a fertilizer plant in Ford County, Kansas, and below is a meat-packing facility near Holcomb, Kansas.
and 1910 near Hereford, after he had examined a pumping plant that had been installed near Portales in 1909. As early as 1911 J. W. Lough was using a Layne pumping plant near Scott City, Kansas, to churn 1,600 gallons of water per minute to the surface (Green 1973, 59-61; Green 1990, 39-40).

ENTHUSIASM AND REALITY

Local boosters showed unbridled enthusiasm over the possibilities for turning the semiarid pastures of the High Plains into a vast oasis of irrigated farms. One T. J. Molinari of Portales boasted that the aquifer contained "oceans of water"; another New Mexico booster added that the region needed only "the magic of the pump" (Green 1990, 36). After J. C. Mohler, assistant secretary to the Kansas State Board of Agriculture, had made a cursory investigation of the wells in western Kansas, he wrote, "These large, deep wells, with the centrifugal pumps and powerful cheap oil-engines, are the means by which the underground waters will be utilized to irrigate the lands of this great territory" (Green 1973, 60-61).

Superlatives flowed from the pen of Zenas E. Black, the secretary of the Commercial Club of Plainview, Texas. In a 1914 article, Black first coined the phrase "The Land of the Underground Rain" in the title and asserted, "The centrifugal pump has lifted the shallow water portions of the Texas plains from bondage to the erratic cloud. In this work it has been assisted by the crude oil and distillate burning engine. The perfection of the above agencies has been the greatest boon that inventors have given the world during the past ten years" (Black 1914, 13; Green 1973, 61).

The enthusiasm of local boosters whitewashed the disadvantages of the early pumping plants. First, costs were beyond the reach of the average farmer. Shallow wells no more than 35 feet deep using the cheaper vertical or horizontal centrifugal pumps could cost as much as $2,300, including labor for digging the well, the pump, and the engine. But the installation of a pitless pump in a deeper well of 25 to 175 feet could range from $4,000 to $6,000 for a turnkey job. In 1913 a 70-horsepower Bessemer engine installed at the well site could cost as much as $1,900. Well-drillers using the new rotary rigs adapted from the Louisiana and Texas oil fields charged from four to five dollars per foot for drilling a 28- to 30-inch-diameter well to accommodate the pump. The Layne pump retailed for about $500. Additional costs, including lumber and labor for constructing a derrick over the drilling site and an engine-house, a concrete base for the engine, expenses for freight, drayage, an air compressor and air tanks, an oil-storage tank and other incidentals, could push the total to another $1,000 or so (Green 1973, 56, 59-60, 113-15).

The early engine was also plagued with mechanical problems. In that
With farm consolidation, many small towns in the High Plains have almost disappeared from the map. Meadville, Nebraska.

Prepower farming era, most farmers had little or no experience repairing internal-combustion engines. Very few owned automobiles before the unveiling of Henry Ford's cheap Model T, first produced on the innovative assembly line in 1913. The farm tractor did not arrive on the scene until World War I when labor shortages in British agriculture, caused by the slaughter of the war, forced engineers in Great Britain to produce experimental models that were readily copied in the United States. Irrigator Roland Loyd, who farmed near Hereford, Texas, filled his diary with comments about the mechanical difficulties he had with his Bessemer engine. On one occasion, he "worked about half of afternoon trying to start pumping outfit" before he "gave it up as bad job and cut weeds rest of afternoon." Loyd was fortunate, however; a mechanic called "Bessemer" Smith residing in Hereford specialized in repairing Bessemer oil-burning engines (Loyd 1914, June 20, August 10; Green 1973, 106–7).

Although farmers did not require a mechanic to adjust the long, broad leather belts that connected the pulleys of their pumps to the flywheels of their engines, the need to make frequent adjustments forced the irrigator to remain near the pumping plant; nor did he leave the pump running at night. If the summer temperature soared, the belt expanded and slipped on the pulley. Nightfall often brought cooler temperatures on the High Plains and a tightening of the belt. Thus the farmer had to
shorten or lengthen the belt to avoid excessive wear on the pump–shaft bearings or slippage on the pulley, which could burn and weaken the belt (Loyd 1914, June 29, July 21, July 30, August 1; Green 1973, 107–8).

Mechanical difficulties and high costs for the pumping plants were only two of the reasons the early movement to exploit the Ogallala Aquifer failed. Other factors included the lack of markets for irrigated crops, the absence of credit to finance the installation of pumping plants, and an adequate amount of rainfall during the 1920s, which literally dampened any enthusiasm for irrigation. Indeed, the early efforts to exploit the aquifer were not really the farmers’ but the boosters’, led by local businessmen and land speculators. Yet a few of the old pumps remained in operation, symbols for the future (Green 1973, 101–18).

**MODERN PUMPING PLANTS**

The modern pumping plant on the High Plains today had its origin during those twin disasters, the Great Depression and the Dust Bowl. Through New Deal government–guaranteed financing, many of the new plants began springing up on the Texas Plains in 1934, when a tobacco-chewing, financially stressed banker from Lockney, Artemus "Artie" Baker, used several government programs and credit from pump and engine manufacturers to install turnkey operations for about $2,000. The farmers who made the plunge into irrigation and debt did so only because they were desperate. As Baker said in later years, "A man who had money wouldn't buy an irrigation well; you had to find a 'poor devil' to buy one." Baker's green Ford with its tobacco-stained driver's side became a familiar sight on the dusty roads of Hale County as he made his sales pitch to farmers (as often to the wife as to the husband). Within a year or so after Artie Baker began to sell farmers on the idea of irrigation, pump companies such as Peerless, Layne and Bowler, Johnston, Byron Jackson, and some local machinery companies began to extend credit to farmers for turnkey jobs (Green 1973, 136–41).

The new plants used a more efficient pump (now called a deep–well turbine pump) developed during the 1920s, probably for municipal water–supply systems. The pump was only about 8- to 10–inches in diameter, with closed, multistage impellers turning inside "bowls." It revolved at much higher revolutions per minute (rpm) than the old pump and was also cheaper to install because it required a well much smaller in diameter than the old pitless pump. The new pump was powered by high-speed multicylindere engines, made for industrial purposes, or by automobile engines, both of which developed considerably more rpm...
than the old 250-rpm oil burners. By 1935 cheap, rebuilt automobile engines manufactured by Ford, Chevrolet, Buick, Pierce Arrow, Studebaker, and others were much in evidence in the fields of the High Plains. In 1938 a new Ford V-8 engine could be purchased for $310, and a 6-cylinder Chevrolet power plant cost $235 (Green 1973, 125-27).

Just as important as the new pump and engine was the new invention linking the two. When geologist/hydrologist Charles L. Baker of the University of Texas investigated the Ogallala Aquifer on the Texas Plains in 1915 he wrote, "Some system of direct connection should be devised in order to get more efficiency" (Baker 1915, 95). As early as 1916, perhaps a year earlier, George E. Green of Plainview, Texas, who had dug or drilled and installed many of the early irrigation wells in Hale County, adapted the basic design of an automobile differential to connect pump and engine. Green called the adaptation with its right-angle meshed gears a "geared-head"; locals later shortened it to "gear-head." He installed the first of his gear-heads, run by a 45-horse-power 4-cylinder Twin City engine in 1917, but the invention did not come into general use until the 1930s. Green, incidentally, was never able to procure a patent on the device, perhaps because of its easily copied simplicity of design. No one ever secured a patent on the gear-head, and by the 1930s other manufacturers such as the Johnson Gear and Manufacturing Company of Berkeley, California, and the Amarillo Machine Shop of Amarillo, Texas, were manufacturing and marketing the device.

The new pumping plants had many advantages. Not only were they more efficient; they were more dependable. Farmers began running their units twenty-four hours a day, significantly increasing their irrigated acreage. In 1919 the average pump watered 72 acres; the new plant by 1937 was irrigating 139 acres. These pumps were also cheaper: The older plants had cost $4,000 to $6,000 installed, but a turnkey job for a 180-foot well using the new pumping plants was about $2,000. That included $835 for the pump, $585 for drilling and casing, $270 for the gear-head, and $310 for the engine. Operating costs were also lower. An acre-foot of water using the older technology ranged from $5.00 to $6.25; costs for the newer plants ran from $3.30, using a Chevrolet 6-cylinder engine, to $4.50, with a Ford V-8 power plant (Green 1973, 127-30).

As exploitation of the Ogallala expanded north from the Texas Plains after World War II, new technology brought about more changes in irrigation practices. Fuel costs were lowered when farmers switched from gasoline to liquified-petroleum, butane/propane gas, or natural gas piped in from the nearby gas fields of the Texas and Oklahoma panhandles and southwestern Kansas. By the late 1950s cheap natural gas, much of it brought to the pumping plants by gas lines laid and financed by farmer-cooperatives, powered most of the pumps.
WATER-DELIVERY SYSTEMS

Significant changes in water-delivery systems also occurred. Rubber, plastic, or aluminum siphon tubes replaced the old labor-intensive method of keeping a laborer with a spade in the field to slice out or fill up sections of the ditch as water was moved from row to row. Underground concrete pipe replaced the ditches, resulting in significant savings in water previously lost to evaporation or soakage. Gated aluminum pipe then transferred the water from the underground pipe via riser valves, easily recognizable from the road by the old tires encircling them as markers so that farmers would not accidentally demolish them with a tractor or a pickup truck (Green 1973, 152-55).

Aluminum pipe was used not only for running water down the rows by gravity, but also in a new method in applying water-sprinkler irrigation. American aluminum companies such as Alcoa and Kaiser had greatly expanded production during World War II to meet the new demand for the lightweight metal in aircraft. In efforts to open up new markets after the war, the companies began manufacturing aluminum pipe. At first, production amounted to only a trickle, with 250 miles of pipe turned out in 1946, but as demand increased, the miles of pipe grew to 7,500 in 1952. Sprinkler irrigation itself was not new; it had existed for decades in orchard and truck farming, where steel galvanized pipe had been permanently set on posts.

But aluminum pipe resulted in the advent of widespread portable sprinkler irrigation, using pipe of 20 to 40 feet in length with quick-locking/quickly detachable coupling devices that could be moved across a field by one person, set by set. W. H. Stout of Portland, Oregon, held the patent to the most popular coupler of the early 1950s, the so-called Stout coupling. Actually, some experiments using steel pipe equipped with fast-coupling devices were carried out in the 1930s, but the pipe was simply too heavy to be carried by one worker. Aluminum pipe was not only lighter than steel; it was also cheaper. Just as important, the shiny new pipe made it possible to irrigate sandy or rolling land, thus setting the stage for expanding the exploitation of the Ogallala into regions previously thought to be unirrigable ("Portable Sprinkler" 1950, 97-98, 132, 134; "Aluminum Pipe" 1953, 132-34; Holman 1957, 76-79).

Early portable irrigation required moving the sets every twelve to twenty-four hours; depending on the total length of pipe, one to two hours might be needed to complete the move. In efforts to save labor costs, inventors experimented with ways to cut the time. W. H. Stout, who held the patent on one of the two basic couplers, invented and began manufacturing the Wheel-Move in 1950, a device in which the pipe passed through the hubs of steel wheels set at intervals to keep the pipe...
off the ground. Moves could then be made much faster, especially by several workers pushing the wheeled pipe to its next set ("Portable Sprinkler" 1950, 98).

INTRODUCTION OF THE CENTER PIVOT SYSTEM

Wheel-Move and its many imitators were soon surpassed by the most significant development in artificial watering since Mahlon Layne patented his pitless pump—the invention of center pivot irrigation. The center pivot was the creation of Frank Zybach, who patented his first model in 1949 when he was farming near Strasburg, Colorado. Suspending the pipe only a couple of feet, the system was originally designed to water sugar beets, which offered a rather limited market in areas already serviced by ditch-flow gravity irrigation. Zybach moved to Columbus, Nebraska, around 1950, where he formed a partnership with A. E. Trobridge, who supplied much of the capital for adapting the system to watering row crops. Another patent was secured in 1952. The next year, Zybach and Trobridge sold the rights to produce and sell the system to Valmont Industries of Valley, Nebraska, which marketed the center pivot under the brand name "Valley." Valley systems, with wires extending from aluminum pipes suspended some 8 feet from the ground and connected to A-frame towers mounted on tandem wheels, began to appear conspicuously on the landscapes of the High Plains from Texas to Nebraska. Airplane passengers flying over the region began to ask their stewardesses about those mysterious green circles, which dotted the landscape by the 1970s.

The early center pivot systems were connected by swivel, either to a well drilled in the center of a quarter-section (160 acres) or to underground pipe laid to the section's center. Diesel engines usually supplied the power. Hydraulic power slowly pivoted Zybach's invention in a circle around the pump and over the field, pushing it over uneven ground and even over hills. The system bled water from the aluminum pipes to power a cylinder and piston at each wheel. The piston used a "Trojan" bar, which acted as a ratchet on the wheels.

Since the initial appearance of the Valley system many other makes of center pivots have been developed, but only a few large brand names remain. Pivots use hydraulic power or, more commonly, electric motors with gear boxes. Most are mounted on pneumatic rubber tires rather than on steel wheels. The earlier systems revolving in perfect circles could not irrigate the corners of the field, so only about 133 of the 160 acres could be watered; a few systems now use a hinged unit that waters the corners. All have in common the virtually complete automation of the irrigation sys-
tern. Except for repairs, the only labor required is in starting and servicing the engine and pump.

Development of the center pivot made it possible for irrigation to expand into the extensive Sandhills of Nebraska, which overlie much of the Ogallala Aquifer. The sudden surge of agricultural commodity prices in 1974 apparently stimulated the rapid development of the systems in Nebraska. In 1973 fewer than 3,000 circle systems were in the state; within six years the state counted 15,000 center pivots, most of which were pumping from the Ogallala. The systems were expensive and employed a high level of energy; by 1976 a center pivot could cost as much as $50,000 installed and it consumed 50 gallons of diesel fuel per acre each year in applying a total of 22 inches of water per season.

The advent of portable sprinkler irrigation has been a mixed blessing for the Ogallala. In the older irrigated areas of the southern High Plains, now plagued with increasingly weaker sources of water as a result of more than half a century of mining the Ogallala, sprinkler systems have conserved water by using the systems to apply only the minimum amount of water to crops and by hanging the sprinkler heads below the aluminum pipe on flexible hoses to reduce water loss through evaporation and drift. But the center pivots have opened to irrigation the Nebraska Sandhills, a fragile ecosystem of sand dunes only a few thousand years old and one of nature’s most productive grazing/hay lands (Splinter 1976, 90-99; Aucoin 1979, 17-20, 38—40; Green 1973, 206-8).

THE LEGACY OF IRRIGATION

To many farmers on the High Plains who made the decision to install pumping plants, irrigation technology has brought relative prosperity and an enhanced standard of living. Yet dependence on these new systems has also created a kind of secular faith that technology is infinitely capable of solving future problems involving overdraft of the Ogallala and pollution of the aquifer caused by chemical fertilizers and pesticides.

When many farmers on the southern Texas Plains were faced with exhaustion of the Ogallala they turned to expensive and massive engineering schemes for importing water from such faraway places as the Mississippi and Missouri rivers and even from Canada. At a symposium in which I participated in 1974, one chamber of commerce representative from a Texas town proposed that the long chain of outer islands along the Texas Gulf Coast be enclosed. The resulting reservoir could be used to impound the waters of Texas rivers, which would then be pumped back uphill to the High Plains. This unbridled faith in technology was expressed by W. D. Rogers in 1976 when he was mayor of Lubbock, Texas:
"The history of this country is that as the need arose for anything, somebody was there with the right tool to take care of it. This is the way this country was built" (Green 1973, 230). Today, this optimism about the efficiency of technology to produce water for the High Plains appears not only to be naive, but in view of growing environmental concerns it is also destructive.

The development of irrigation technology in the region during the twentieth century provides us with a key to the origins of this attitude. The appearance of the centrifugal pitless pump, the hot-ball engine, and the rotary well-drilling rig demonstrated that the Ogallala held massive amounts of water that could be exploited for croplands. The technology then evolved into a cheaper, smaller, and more efficient pumping plant, thanks to the invention of cheap 6- and 8-cylinder automobile engines, the closed impeller pump, and the pump gear-head. The labor-efficient center pivot sprinkler system appeared as a kind of capstone in the evolution of pump-irrigation. With this historical perspective in mind, it is easy to understand why the people of the Ogallala look to technology for the answers to problems of both the present and the future.

REFERENCES

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