THE QUEST FOR WATER IN NEW MEXICO

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TECHNICAL COMPLETION REPORT
Project No. A-026-NMEX

New Mexico Water Resources Research Institute
in cooperation with
Department of Humanities, New Mexico Institute of Mining and Technology
Socorro, New Mexico 87801

August 1973

The work upon which this publication is based was supported in part by funds provided through the New Mexico Water Resources Research Institute by the United States Department of Interior, Office of Water Resources Research, as authorized under the Water Resources Research Act of 1964, Public Law 88-379, under project number: A-026-NMEX.

ACKNOWLEDGEMENTS

In addition to the New Mexico Water Resources Research Institute and the Office of Water Research who supplied the funds which permitted the research, plus much valuable assistance during the period of the grant, the following agencies and organizations were exceedingly helpful:

Bancroft Library, University of California, Berkeley, California.

Bureau of Land Management, New Mexico State Headquarters and New Mexico Regional Offices.

Coronado Library, University of New Mexico, Albuquerque, New Mexico.

Department of Hydrology, New Mexico Institute of Mining and Technology, Socorro, New Mexico.

National Archives, Washington, D. C.

New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico.

New Mexico State Engineer, Santa Fe, New Mexico.

New Mexico State Records Center and Archive, Santa Fe, New Mexico.

United States Department of Agriculture, Albuquerque, New Mexico.

United States Soil Conservation Service, Albuquerque and Socorro Offices.

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BY

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ABSTRACT

This study assembled historical data relating to water control and applied technology during Indian, Spanish, and Anglo-American periods in New Mexico. In addition, historic forces, such as law, social institutions, economic habits, irrigation practices, and transportation, affecting the development of water resources were laid out and evaluated, thereby giving a comparison of efforts and applications across the three major cultures making up New Mexico's historical pattern.

The arid nature of New Mexico's climate forced all of its inhabitants, Indian, Spaniard, and Anglo-American alike, into maximum technical efforts toward water control. The Indian and the Spaniard tended to utilize similar techniques, and generally lived in proximity to one another. They both practices subsistence agriculture. Both Indian and Spanish villages have, by-and-large, clung to methods centuries old and have not had the opportunity or desire to utilize new scientific and technological advances. On the other hand, the American settled in unoccupied areas, practiced commercial agriculture, and applied massive technology to water development. This heavy technical application in the major water courses resulted in important economic advances, but has also created serious problems which can only be solved by even more massive applications of technology. The history that unfolded told of a well-advanced technology backed by sound scientific principles, blended with a primitive simplicity mixed with superstitions, old wives' tales, magic, and faith.

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INDIAN QUEST FOR WATER

Prehistoric Technology

Until the beginning of the Christian era in our dating system, man in the Southwest was a food gatherer and hunter. His simple technology was directed toward developing tools for hunting; the remainder of his food supply came directly from nature. After the Christian era opened, man in the Southwest evolved into an agriculturalist, and with that development he redirected some of his technology toward water resource control.

In the mind of aboriginal man in New Mexico, water and water resources came from benevolent gods, and were, like the Indians themselves, a part of nature. During the thousands of years when the Indian was the sole occupant of the Southwest, his use of water, except for drinking, was scanty and largely accidental. Primitive man was not a technologist; that is, technology was not a designed part of his culture or his philosophy. His technical acts were not distinguished from his natural ones. He saw the lighting of a fire or the use of a spring or stream in the same sense that he saw his ability to walk or to use his arms. His technical acts and his natural acts he thought of as a given stock fixed once and for all. The art of invention, so much a part of the culture of modern man, was not revealed to primitive man. In the course of constant manipulation of a multitude of objects in nature, primitive man suddenly and by mere chance came upon a new and useful device. Invention in primitive society appeared as another aspect of nature, a part of nature's power to furnish man with certain novel and useful things. Thus it was with water. The Indian utilized what he found free in nature or was able to imply from nature.

It is also important to point out that primitive man in New Mexico was highly subject to climatic change. Changes in effective moisture could cause dramatic change either in food producing techniques or in population shifts. The Indian, because of the low level of his technology, could not alter nature very much or even adapt to nature by technical application.[1*]

[1*] *Superscripts refer to items in "LITERATURE CITED" section.*

When the possibility of domestication of plants was revealed to man, so was the possibility of water control. Despite the fact that the Indian's technology was very limited, he did utilize what little he had for the development of water resources. The aridity made application of technology to water resource development a necessity. Only in isolated high mountain valleys did enough rain fall for dry farming techniques to be applied. Elsewhere in this dry land, natural rainfall had to be supplemented in some fashion.

Indian need for water technology was expressed in two kinds of development: first, that technology evolving from his need for drinking water, and second that technology emerging from his need for water for his crops. The latter produced the broadest application of technology, although not necessarily the highest level of technology.

Domestic water, in most cases, came from natural sources. The pueblos of New Mexico were generally located by streams or springs and little or no development was necessary to acquire water.[2] In some instances, human labor and whatever primitive tools were available were applied to improve a natural water source. These took simple forms. Small brush, dirt, or rock dams were frequently built in streams to form small pools from which to draw water. Springs of seeps were often dug out, thereby forming pools or cisterns. A well has been excavated at Trechado Springs on Mariana Mesa south of Zuni: it was a walk-in well or clay pit, or both.[3] On Turkey Ridge, just west of Gran Quivira, is an abandoned Saline pueblo of nearly 200 rooms which has a very evident cistern nearly thirty feet across. It was dug down four to five feet to a gravel layer which at one time carried water to fill the artificial basin.[4] At Acoma pueblo, nature provided the cistern, or as described by Fray Benevidas "there is a cistern which God made in the rock itself."[5] In the winter the Acoma people collected all the snow they could into the cistern to aid in their water supply. To keep the water clean they kept the area around the cistern carefully swept.[6] Beyond these simple kinds of effort, little could be done to improve upon sources of domestic water.

There was, however, one other important technical development which, at least in part, resulted from need for domestic water. This was the evolution of pottery capable of holding water. In terms of the complicated methods learned and the great variety of raw materials necessary for the development of glazed and fired pottery, this might well be the high point of Indian technology. Pottery brought water into the Indian's dwelling in sufficient quantities to revolutionize his living style.

The Indian's need for water for his crops was a critical force in his life style after a sedentary agricultural society emerged. When natural rainfall failed to produce enough water, he was forced to utilize his limited technology and his limited knowledge of natural law to increase the water in his fields; in short, he had to irrigate. Direct evidence varies from site to site, but enough has been found by archaeologists to indicate that the ancient inhabitants possessed considerable skills in the art of irrigation and water control.[6]

There were many areas throughout the Southwest where various prehistoric people developed societies capable of applying a limited stone technology to the development and control of water. These ancient people, only a few of which still occupy their traditional lands, left a record amid the ruins of their houses, fields, and water systems which tells in sketchy fashion of their efforts to harness the forces of their environment. In a multitude of places and in a variety of ways they worked out methods to utilize the scanty water in the arid lands. An overview of who they were must precede the discussion of the devices they used.

The Hay Hollow Valley on the upper Little Colorado River near Snowflake, Arizona, was the site for work done in 1969 by the Southwest Archaeological Expedition of the Field Museum of Natural History. Evidence of water control devices was carbon-dated at A.D. 1000 to A.D. 1300.

In the Vosberg region, 85 miles northeast of Phoenix, usage of water control devices was in evidence prior to A.D. 1000 up to 1375 A.D. By 1050 A.D., major systems were formed--evidence that the inhabitants were controlling, at least to some extent, their environment. These devices improved until 1375, after which the area was gradually abandoned.

The Rio Grande Valley was the site for numerous settlements of Pueblo peoples, one of which was the Tewas. They entered the area late, perhaps from more northern homelands in search of irrigable land. Among another Pueblo people, the Keras, there is little evidence of irrigation, although they could not have been ignorant of the techniques since, in an 1890 excavation, Bandelier found some evidence of irrigation. But most of the knowledge of Rio Grande Pueblo peoples today comes from a study of present-day pueblos in the upper Rio Grande by Florence Ellis in 1967. Irrigation may go back as far as A.D. 1000 and most certainly into the 1200's, but major use seems to have come after the drought of 1500. Not long after that the Spaniards found irrigation flourishing.

In the Galisteo Basin, southeast of Santa Fe, at least four pueblos, probably of the Pueblo III period, A.D. 1100-1300, had water control technology at a corresponding level and time.

Very little is known about the Pueblo peoples of the northern San Juan Basin. It has been found, however, that by the Pueblo III period, sedentary agricultural peoples had developed several devices for regulating and controlling water supplies. Chaco Canyon exhibits similar details of the prehistoric life there.

The Kayenta Anasazi of the Mesa Verde area and the Four-corners area seem to have developed a complex system of water control as far back as 500 A.D., but the major developments did not come until the 11th or 12th centuries. From 1150 to 1300 they seem to have lived under stable climatic conditions, and water control devices were numerous. But from 1300 onward, their use of water control systems declined because of climatic stresses.

In the Casas Grandes area of Old Mexico, water control devices were developed around 1050 and grew into a 5-mountain system. From 1050 to 1250, population increased, forming a complex agricultural society. At its height, Casas Grandes occupied almost half of the area from 29 40' north latitude to 108 55' west latitude--more than 12,000 square kilometers of land. Water control safeguarded nearly 80,000 hectares of rich bottomland. The area was abandoned between 1300 and 1400 A.D. because social stresses or climatic changes proved too exacting.

Generally, it can be said that the primary period for development of water control devices was between 1000 and 1300 A.D. In most areas, except the Rio Grande Valley, abandonment came about 1300-1400 A.D.

Archaeologists can never know the reasons for the development of water control devices among the prehistoric Indians of the Southwest. But, based on modern social science techniques, hypotheses can be drawn. Variables include social stress, climatic change, human curiosity and subsequent experimentation. But as to exact cause-effect, the answers are lost in antiquity and are therefore always open to speculation. Small systems could have been constructed by small kin groups, but one point is clear: the large, more complex systems, such as Casas Grandes, had to have been built by larger groups. This suggests that large groups settled together to build these systems.

Water control devices found in various parts of the Southwest by archaeologists showed an amazing level of development for people so primitive. These devices differed in various localities as conditions of runoff, rainfall, and evaporation varied. Types of devices found in the prehistoric Southwest included check dams, diversions, terracing, canals, ditches, linear and grid borders, field check borders, and dams and reservoirs.

Check dams were widely used in New Mexico and in surrounding areas. In the Vosberg area check dams were made out of boulders and unworked indigenous materials. They were either straight or slightly concave, and were placed perpendicular to intermittent drainage to retain soil and runoff. The result was the formation of relatively small alluvial plots which were readily farmed by hand cultivation. The ends of the crude dams were buttressed against the sides of the drainage ditches, and therefore there was a correlation between the length of the structures and the width of the drainages in which they were situated.[8]

At Casas Grandes, Mexico, a sophisticated system of dams, diversions, and ditches was built which carried a large volume of water. Check dams were placed on steep hills and at right angles across arroyos, sometimes with gradients of up to 30°. Check dams made up nearly 84 percent of the system. They were .09 m to 3.75 m high and were so set that the top of one was level with the base of the next upslope wall. Since they collected silt as well as water they had to be continually moved upward until sometimes the arroyo was completely filled in. Frequently they were staggered to force the runoff down the slope in a zig-zag manner, thus slowing it down and better controlling it. At the bottom of the slope and arroyo system was reservoir and ditch construction which helped to distribute the flood waters.[9]

Check dams appeared in the northern San Juan area in the period 1100-1300 A.D. They were constructed of rough stone to impede runoff but not to halt it. It was slowed down and trapped on terraces to increase soil moisture.

These structures also enhanced soil potential by building up the terraces by collecting loose fertile soils carried by the flood waters.[10] At the Richfield site, between Springerville and St. Johns on the upper Little Colorado River, check dams as well as distribution canals were also found. The canals were protected from a cross-cutting arroyo by the dams.[11] In the Kayenta region, check dams were found across rock-walled gullies and arroyos. They were made from earth, masonry, and masonry with earth cores. In some cases they seem to have been built to check and contain soil as well as run-off.[12]

Bandelier mentioned having seen check dams in the area of the Tewa Pueblos of the upper Rio Grande Valley of New Mexico. Like other areas, they were constructed across normally dry arroyos to catch floodwater run-off.[13] At Zuni there was no evidence of water control devices but it is implied by known ethnographic and ethnohistoric data that they are merely undiscovered.[14]

Along the Gila River in western Arizona, near Pima, there are several excellent examples of check dams. One, an area of nearly 25 acres, is laid out with simple water detention boulders forming a complete spreading system. Detention structures were roughly rectangular in shape and varied in size from 8 by 10 feet to 24 by 30 feet. Grades on the gently sloping country were 2.5 to 3.5 percent. Some terracing was also apparent. The terraces ranged from 14 to 18 feet in width and extended from 180 to 225 feet in length.[15]

Diversions, the second important prehistoric water control method, included dams and walls. In most cases they were similar architecturally to check dams, but differed in function. They tended to be sturdier and showed better construction. They frequently resembled riverside terraces but functioned as diversions rather than as retention or holding devices.[16]

At Casas Grandes no diversionary devices have been reported. It is inferred, however, from the complexity of the system, that they did exist. Diversions in the northern San Juan were used to redirect natural water flow into channels. Turning sheet-runoff into a ditch was the most common means of collecting water. The most elaborate system yet recorded was the system of ditches feeding Mummy Lake, on Chapin Mesa, at Mesa Verde, Colorado.[17] The facilities for water control at the Hay Hollow locality on the upper

Colorado River included a diversionary dam. At the intersection of two canals there was found a dam which allowed the flow of water through a main channel or diverted it into a smaller feeder canal. The facility was dated by radio-carbon as A.D. 1000-1300.[18] The Kayenta had also developed techniques for diverting floodwater by the middle of the twelfth century A.D.[19]

Below Nambe, at the Pueblo of Pojoaque, one of the Upper Rio Grande Pueblos, a diversion ditch led water along the edge of Pueblo IV dwellings, diverting some to garden terraces on the steep north slope. At San Juan Pueblo, on the Chama River, several diversionary dams lay at an angle in the stream. In swifter waters they were held by piles of woven wickerwork filled with stones. A few of these survived into the present.[20] Diversions, like check dams, were an important result of applied technology and were in evidence throughout New Mexico and the Southwest.

Terracing and related devices, such as ridge walls, riverside terraces, and canals, make up another area of prehistoric Indian control of water. In the Vosberg area ridge walls were found situated on alluvial and colluvial lands, constructed of fist-sized cobbles. Their function was to retard the loss of runoff by building up ridges to prevent the draining of agricultural terraces or garden plots.[21] Casas Grandes utilized riverside terraces as a part of their great water control system. These were dams across main drainages which spread out and trapped runoff, thereby improving both soil moisture and soil depth.[22]

Canals were an integral part of water control systems in the upper Little Colorado River at the Hay Hollow site. There a main canal carried water from Hay Hollow wash a half mile along a semi-circular route to agricultural areas. In the County Road site, two canals carried water to farm plots. At Richfield site, two canals dating from 1300-1500 A.D. were found.[23]

Ditches were everywhere in evidence in the Southwest and, while difficult to find in areas where subsequent occupations took place, enough have been found in a variety of sites to assure us that knowledge of ditch techniques was far advanced in the prehistoric Southwest. One of the most complex ditch systems is in the Kayenta region. The ditches were rock and earth-lined and were fed from reservoirs or other ditches carrying flood runoff.[24] In the northern San Juan, at Mesa Verde, there was an extensive ditch system which was part of the Mummy Lake complex.[25]

The Pueblo peoples of New Mexico developed extensive ditch systems. Bandelier found that the Piro Indians of the middle Rio Grande Valley constructed two ditches to provide water for garden plots. At Nambe, water was taken through ditches to lands favorable for farming: one of the Nambe ditches dated to around the fourteenth century. In the thirteenth century, Tesuque Pueblo irrigated some of its fields by two ditches: one ditch started near the present highway bridge over the Tesuque River, the other ran from Bishops Lodge down the side of the valley of the present Rio en Medio road. Four ditches were reported to have been used at San Ildefonso Pueblo, say their oldtimers. It is known they had two ditches on each side of the Rio Grande. Santa Clara also used ditches tapping the Rio Grande river.[26]

Use of stone retaining walls around garden plots was common through the Southwest. While these served to retain soil and outline the plot, they also served as water conservation and control devices. Crescent-shaped walls are unique at Vosberg. They were constructed of cobble masonry and formed garden plots behind the crescents. They varied in size from 5 to 8 meters in length and 45 to 65 centimeters in width. They were located on gentle slopes.[27] In the Richfield area of the upper Little Colorado River, plots were bounded on three sides: the uppermost side was left open in order to collect the runoff.[28] Bandelier mentioned having seen stone outlined garden plots at the ruins of Sapawe near El Rito, New Mexico.[29]

Linear borders at the Vosberg site were located on alluvial slopes, and the grid borders were located on colluvial substrata. In both cases they resembled those on the Chapin Mesa in the Mesa Verde.[30] The Kayenta built linear alignments of cobbles and a combination of slabs and cobbles bordering a bed of soil to retain both soil and moisture in the plot.[31] Sheet flooding was controlled by this means at Casas Grandes in Mexico.[32] Field checking worked well on slopes ranging from three to six degrees. Again, this method utilized sheet water during the rainy season. Rock and earth were built up along contours of the slopes at varying intervals from top to bottom. These served two purposes: they slowed down the runoff along the slope, trapping and holding small amounts of the water, thus allowing some runoff to penetrate the soils; and they also caused a crude terracing as silt carried in the runoff was deposited behind each succeeding field dam, thereby improving soil depth and consistency to a small degree.[33] In the

Chaco Canyon area the Pueblo Bonito farmers located their fields in the paths of sheet water runoff, and thus multiplied the effect of a single rain many times over.[34] The village of Zuni might well have been so located because of the fact that water from several small streams leading into the area spread out in thin sheets over a large area, thereby making possible rudimentary agriculture.[35] "Floodwater" methods of irrigation are still practiced by Southwestern tribes.[36]

Reservoirs were found in many areas. Two stone-rimmed tanks cut 10 feet into bedrock and plastered with 10 inches of polished clay were found in the Piro area in the middle Rio Grande. South of San Cristobal, remains of a bounded earthen dam and reservoir described as 300 feet long, 50 feet through the base, and about 5 feet high were found. At the Coronado Pueblo an adobe dam was located whose ruins rose 10 to 12 feet above the surface. At the Ruins of the Pueblo She there was a dam 160 feet long and 20 feet high. All the above dam and reservoir complexes were fed by flood runoff, not by perennial streams.[37] At Pueblo San Lazaro in the Galisteo basin there was a dam 125 feet long made of adobe and brick. At Pueblo Lanco, also in the Galisteo basin, three reservoirs were apparent. One was in the court of the Pueblo, a second one was 700 feet north of the Pueblo, and a third was made by shutting off a small ravine 400 yards west of the Pueblo.[38] Reservoirs have also been reported at Chaco Canyon: the best known are at Pueblo Pintado, Kin-Ya-A, and Penasco Blanco.[39] Mummy Lake, on the Mesa Verde, used artificial reservoirs exclusively for water storage. At Kayenta, pot-holes and pools cut in bedrock, with dams when necessary, were used to form reservoirs.[40] Chaco Canyon had a masonry dam 130 feet long, 20 feet wide, and 7 feet high. A gate in the center was 3.25 feet wide. The dam collected runoff, probably stored it, and diverted water into the canal through gates. The nearest towns were Pueblo Alto and Pueblo del Arroyo.[41]

Where springs gave sufficient flow for both domestic use and irrigation, they were so used; never an important source of irrigation water, they were, nevertheless, often diverted to fields. The spring within the walls surrounding the pueblo at Pecos (Cicuye) showed signs of being diverted outside the enclosure into the surrounding fields.[42]

In the Mimbres Valley, at the Swartz Ruin in Grant County, irrigation by ditches would have been easy because of the topography. But if there were ever any prehistoric canals or ditches they are lost and there is no evidence that they ever existed.[44] Little residue of ditch irrigation has been found in the ancient ruins of the Chama Valley.[45] In the Jemez Mountains only the most primitive types of irrigation were used. Puye Ruin had an irrigation system, but it was probably built by later occupants, not by the original inhabitants.[46] The most extensive Indian irrigation system in New Mexico was at Gran Chaco in the northwestern part of the State.[47] In addition to the very ancient ditches recently found, systems traceable to early Navajo efforts have also been located.[48]

Since much of the agriculture prior to the twelfth century was carried out on the mesas and plateaus above small canyons, ditch irrigation was not possible with the technology available. In those areas, both in the early periods and in those years just preceding Spanish occupation, floodwaters were utilized in various fashions to irrigate Indian fields. Sometimes this involved crude dams across normally dry arroyos to cause floodwaters to spread out across a wider plain than normal in the arroyo bottom or onto low adjacent benches used for fields.[49]

While there are a number of references by early Spanish explorers and colonizers regarding Indian irrigation, very little detail is ever included. Antonio de Espejo, who visited the pueblos of New Mexico in 1582, makes several references to Indian irrigation, but without detail.[50] After Spanish occupation in 1598, early Indian knowledge of ditch irrigation is increasingly mentioned.[51] The problem in really understanding the level of ditch use lies in the primitive nature of Indian technology. The materials they used, brush, easily handled gravels, dirt without the capability of using any cementing compounds, and little rock, meant that what they did was easily lost by flood.[52] In addition, ditches were frequently shallow and near the rivers which meant they were easily and totally destroyed by high water. Finally, with the importation of improved irrigation techniques by the Spanish after 1598, those Indian ditches in use were incorporated into the new systems, deepened, or otherwise changed leaving no evidence or knowledge of earlier ditches. It is probably safe to say that ditch irrigation from rivers and streams was practiced in two primary areas: the ancient ruins of Gran Chaco, and in the pueblos which emerged along the Rio Grande and its tributaries in the several centuries preceding Spanish occupation.

While there was little technology used in any of the efforts to develop water, Indian culture was deeply committed to water control. Even utilizing his technology to the fullest the Indian was still subject to the whims of nature. Lack of rainfall made mockery of his efforts at stream or field check-dams. Too much rainfall washed out his efforts in a flash. Water control to the Indian was in the hands of his gods. Religious cults devoted to the worship of water prevail throughout all of New Mexico, and numerous assumed ritual objects have been found associated with streams or surface water.[53] Pictograph sites and shrines of the early Navajos at the junction of the San Juan River and Pine Creek possibly give an indication that water played a spiritual role in early Navajo culture.[54]

The Indian's quest for water in New Mexico was a mixture of reliance on his native gods, the ability of nature to supply water as rainfall and as streams and springs, and on the rudimentary technology he was able to muster. These later efforts were usually primitive, inefficient, and undependable. Nonetheless, the Indians were able to build, at several different periods, substantial societies based upon irrigated agriculture

SPANISH QUEST FOR WATER

The coming of the Spaniard permanently into New Mexico, dated with the colonization by Juan de Onate in 1598, did not greatly change the life styles of the people of the region. The Spanish became agriculturalists as were the Indians before them. They were subject to the same natural forces, typical of arid lands, as were the Indians. Only in the area of their technology was there a marked improvement. Indian technology reflected stone age tool making, with all of the limitations this suggests. Spanish technology, on the other hand, was representative of sixteenth century European culture, a jump ahead of several milleniums when compared with Indian levels. This meant dramatic change in New Mexico.

The Spanish brought advanced metallurgical techniques and metal tools which made control of their environment easier. While the Spanish in New Mexico never had metal tools in any great quantity, due to the difficulty of transporting them from Mexico (there was little local production during the colonial period), enough were available to give the Spanish a pool of capital which was used to manufacture other tools, mostly from wood.[55]

The Spanish also introduced domesticated animals from which were produced various food products, fuels, and, most important, leather. Leather was widely used for making buckets, clothing, harnesses, wagon springs, fastening devices of all kinds, and often as a tool in the construction of ditches or other irrigation works. Excavated earth and rock was frequently hauled away as waste, or to other locations as fill, on rawhides pulled by oxen.[56]

Added to the new technical capability were engineering skills which, while still rudimentary, were far in advance of the Indians. New Mexico never achieved the same level of engineering skill, the heavy tools, nor the surveying techniques and instruments which were available in Spain and even in Mexico. In New Mexico the water control works were simpler, and more reliance was placed upon the "art" rather than upon the "science" of irrigation.[57] The Franciscan fathers who controlled the Indian missions, and the simple soldier-farmers who had to make a living in arid New Mexico, knew the general theory of surface water flow, and were able to apply it, in a fashion.

As important to water control as their technology were Spanish political, legal, and social institutions relating to land and water use. Spain had a long heritage of irrigation practice, probably learned from the Moors who controlled Spain, at least in part, from 711 to 1492 A.D. The very word acequia, the Spanish word for ditch, is from the Arabic.[58] It was natural that the Spanish brought with them to New Mexico this deep heritage. The remarkable part of the culture built on irrigation was not so much the engineering works or canalization and the brush and rock diversion dams, but the social order of villages revolving around the necessity of operation and maintenance of these works and systems.[59] The Mayordomo de la Acequia, or ditch master, was one of the foremost citizens of the village, for it fell upon him to placate every farmer who felt that he did not get his fair share of water and also to prod each irrigator to contribute his share of the labor necessary for maintaining the system. But this social order, highly dependent on subsistence irrigated farms, was equally dependent on the grazing resources in the adjacent non-arable hills and in the forested lands. The livestock industry was the source of those animal products--wool, leather, meat, and draft power--necessary to supplement the agricultural products, beans, melons, corn, and chili.[60] This kind of system, so dependent upon the technical capability brought by the Spanish, was also far advanced when compared to the Indian systems, at least in terms of efficiency and production. A legal system administered generally throughout the Spanish colonies reinforced both rules on water use and land ownership, giving a great unity to the village systems found in New Mexico. Irrigated agriculture, both from a technical as well as a social point of view, was already a way of life for the Spaniards when they arrived in New Mexico in 1598.[61] It should be pointed out, however, that the Spanish state did not participate directly in local affairs in such matters as internal improvements; that is, they did not build the dams, ditches, and roads. This was left to the individuals, recipients of land grants, and to communities.

The Spanish put their skills and know-how to work immediately upon locating their first "capital" at San Juan de los Caballeros, near modern San Juan Pueblo. The first Spanish acequia was dug, with aid from Indians from San Juan who were pressed into service, in late 1598, so that they were ready for spring planting.[62] This initial effort, and subsequent efforts at other villages, required a considerable amount of labor and much trial and error. To test the fall of an acequia under construction required water to be turned into it frequently to check the grade. These simple ditches were not always able to follow the best courses, for such obstacles as trees, large boulders, and other obstructions were too much for the simple technology and had to be detoured around.[63] Diversions were also difficult for the Spanish. Where the water supply was adequate and fairly constant, wing diversions or jettys were sufficient to turn water into the acequia.[64] On less reliable streams, where water was difficult to turn into the ditch, dams, called presas, had to be formed. A traditional-style dam on this type of stream was described by James W. Abert in 1856 as "very large, constructed of crib-work, 12 feet wide, and 8 feet high, and 100 feet long, formed of rough logs, and the interior filled with stones and earth."[65] The water thus trapped formed a reservoir which fed the ditch. Jettys or river diversions were similarly constructed. Excessively high water easily washed out such primitive structures and they were constantly being rebuilt.

Once a diversion was made and the ditch carried water it was necessary to construct lateral channels (contra acequias or sangrias) to individual farm plots, where the farmer, with hoe or shovel, guided the water by the construction of small earth partitions to sections of his field, "depressing eminences and filling sinks, and causing the water to spread regularly over the surface."[66] A long day's work resulted in about five acres irrigated by this slow and tedious process.[67] A study of farm sites in the 1850's showed that single farms average only ten acres in most parts of northern New Mexico where most of the Spaniards lived. Undoubtedly this was true during most of the earlier periods.[68]

As the Spanish consolidated and expanded their control over New Mexico they also expanded their irrigation systems. The Pueblo revolt of 1680 halted them temporarily, but following the reconquest by Diego de Vargas in 1692, the development of irrigation continued. Specific information on each system which evolved and the technology used is scarce. Primitive hoes and shovels of wood were used because of the absence of iron in colonial New Mexico.[69] Earth was moved on rawhide drawn by draft animals, or back-packed if animals were unavailable. Main acequias constructed with these simple tools average from three to five yards wide and from two to six feet deep.[70]

The fact that most valleys in north-central New Mexico that had perennial flowing water, even a small amount, had an irrigation system and supported a village of Indians or Spanish farmers is evidence of the persistence of an energetic people utilizing to the fullest the available technology.

Visitors to New Mexico who left us descriptions of what they found in the province frequently mentioned whether or not ditch irrigation was being used by Spanish and Indian communities. Land grant documents gave hints of irrigation systems, and sometimes quite clear descriptions of some ditches. Unfortunately these records do not discuss the technology involved in construction, and the records found in the Spanish Archives of New Mexico in Santa Fe are not complete.[71] The canals in Santa Fe were built early, the first with the construction of the town in 1610. A canal to the north, known after reconquest as the Acequia de la Muralla, was a lateral ditch and brought water to the vicinity of the plaza and the Palace of the Governors.[72] There was also a small acequia, leading from a marsh or cienega, that ran by the plaza near the parish church.[73] It was reported in 1716 that the runoff from the Santa Fe River was sufficient to irrigate all cultivated areas. A map of 1768 shows two main irrigation ditches beside the Santa Fe River.[74] Also, in 1716, it was recorded that the first wells were dug at Santa Fe for domestic as well as stock water. These were shallow, hand dug wells and produced little water.[75] The ancient water lift, or <u>noria</u> (again, an Arabic word), which supplied acequias from a well, apparently was never used in New Mexico, although it did appear in some of the north Mexican provinces.[76] In the middle Rio Puerco Valley, irrigation works appeared in the late colonial period and a considerable system was apparent.[77] In southern New Mexico, around El Paso del Norte (modern Ciudad Juarez), extensive irrigation was reported. The Bishop Tamaron, who visited New Mexico in 1760, reported a large irrigation ditch capable of receiving half of the flow on the Rio Grande. Subsidiary canals led to broad plains and irrigated fields of grain and vineyards.[78] In 1776 the El Paso Branch of the Holy Gospel of Franciscan Observants of New Spain "consisted of a Spanish Villa and 4 Indian pueblos. Both the Villa and the pueblos are supplied with water by the said river (del Norte) and are established on the west bank."[79] Nearby, in the valleys of Rincon and Mesilla, surface water irrigation began in the early 1700's.[80] The report of Fray Dominguez in 1776 indicated that very few of the mission communities he visited lack ditch irrigation facilities.[81]

All of this Spanish activity had its effect on Indian irrigation. It is apparent that Spanish practices, such as organization of labor under a Majordomo and techniques of dam and acequia construction, and the tools of the Spaniards, were gradually adopted by the pueblos. They continued to retain, however, ancient ceremonial practices surrounding irrigation, such as the planting of prayer sticks in the ditches and ritual dances following the cleaning of the acequias in the spring.[82]

Water use and control at Zuni and adjacent areas was reported in two sources. In 1776, irrigation at the pueblo was described:

> The pueblo has no river, but an arroyo which flows only in heavy rain; or when the snow melts. And then when this does not occur, they rely upon a number of wells, some of which have good water. . . .[83]

In a letter on Nov. 25, 1776, concerning irrigation in the area, Bernardo de Micra y Pacheco wrote:

> We found a small but beautiful farm, and a ranch of these Indians (Yutas Payuchis), but did not see any of them. Perhaps they were in the nearby sierras gathering pinon. On the said farm, which has several springs of good water to irrigate, they had sewn maize, frijoles, etc. . . . .[84]

By 1776, the Indians at Nambe Mission practiced irrigation.

> They have almost as much land above the pueblo as below it, and it occupies most of the site mentioned, although a great arroyo that arises in the east-northeast and runs to the southwest until it enters the pueblo's river behind the church and convent, and in front of the canals. . . . They irrigate the upper lands with a mother ditch from well upstream, and they take water for the lower lands from the same ditch a little before the said arroyo empties into the river.[85]

The Indian land at Pojoaque was described in 1773, in the Martinez Land Grant:

> The lands of the natives of said pueblo. . . is bordered on the north side by a main ditch which crosses the main road. . . on the south side, by a small ditch, before coming into the river, by which the Indians irrigate their little garden. . . .[86] And in 1776, the "lands were irrigated by ditches used by both Indians and settlers. . . ."[87]

At the Cochiti Mission in 1776:

> All important farmlands which this pueblo owns lie on the east side of the river (Del Norte) . . . all take the water of the . . . river for irrigation through deep, wide ditches. . . . very abundant crops. . . .[88]

And irrigation was also practiced at the Galisteo Mission among the Indians in 1776.[89]

In 1689, on the Pueblo de Acoma grant:

> The Indians understood the use of water for irrigation. In pre-Spanish times, and around the ruins, evidence of irrigating ditches have been found.[90]

At the Laguna Pueblo and mission, irrigation was found "2.5 leagues from the mission of Cebolleta."[91] In 1776, at the Albuquerque Mission, irrigation was also found. At Carnve, 2 leagues east of the farmlands was irrigated. It was abandoned in the late 1770's because of continual Apache raids. At Nutrias, a ranch was irrigated.[92]

The non-sedentary Indians of New Mexico did not adapt to the new ways very quickly and though they used some of the floodwater techniques learned from other Indian groups, no ditch irrigation was apparent.[93]

Little change in technique or general social structure of the irrigation village life was visible following the end of the Spanish colonial period and on through the 25 years of Mexican domination of New Mexico.

The Indian, Spanish, and Mexican quest for water was an intense one, but it was always limited by their technology. The human effort had to be great in order to maintain an agricultural-pastoral society, the only one available in their time. The result was a ditch irrigation culture with a very strong and complicated set of institutions which pervaded over most aspects of life. Isolation was a part of this system. People lived separately, partly because of the rough terrain of northern New Mexico, but also because of their intense desire to protect their water system and their fields. As a result they were conservative in nature, resisting change, resisting outside influences, relying upon family, church, and village for their intellectual and technical sustenance. The deepness of this cultural pattern was, in part, determined by their technology. In short, they had little choice in the formative years of the eighteenth century to do any more than they did. The villages and small towns of northern New Mexico today are very much like they were 200 years ago, at least so far as their control of water is concerned. One could use literally dozens of small communities as examples to support this conclusion. The little village of Bibo, north of the Laguna Pueblo, Las Trampas, Cundiyo, and Truchas in the rugged Sangre de Cristo mountains, and numerous other communities having their origins in the Spanish period, are prime examples of this kind of cultural pattern. Many of the Indian pueblos of the Rio Grande Valley and its tributaries show a similar pattern. Why is this the case? Why have not these people accepted the variety of technology available to them over the last hundred years? The reason traces back to this strong social system associated with ditch irrigation. To bring in modern dams and ditch systems in the tradition of the Bureau of Reclamation or Corps of Engineers, with all of the advanced technology this would imply, would certainly improve their water systems, possibly their standards of living, but it would destroy a social system hundreds of years old. This social heritage has its roots deep in the soils of Spain and in the ancient Indian pueblos.

EARLY AMERICAN QUEST FOR WATER

1846-1880

Lasting and deep American influences in New Mexico began with the opening of the Santa Fe Trail in 1821. There had been earlier contacts, but they were passing and had not resulted in many Americans living in New Mexico or in making a very lasting contribution to New Mexico life and culture. After 1821 the American presence, resulting from increasing trade relations, gradually turned New Mexico's focus of interest from Mexico to the south to the United States to the east. More and more American citizens became New Mexicans, and as was the case so often in other areas of the West, it was not long before the flag of the United States followed the people. When Stephen F. Kearney came in 1846 at the head of an invading army, the citizens of New Mexico chose not to resist this new force and New Mexico was quickly incorporated into the United States. With American occupation came both good and bad influences. The Anglo-Americans brought capital and technology, two items desperately needed. They brought increased trade with few, if any, restrictions, a boon to New Mexico's economy. They brought a dynamic, ambitious, land hungry, agressive, and Protestant culture, one which tended to look down on the quiet, conservative, agricultural-pastoral, Catholic Spanish and Indian cultures. They came to dominate and they dominated. Also with the American came a new legal system, one that the Spanish and Indian population found hard to understand. It threw land ownership and water rights status into a state of confusion which led to misunderstanding, fraud, and bitterness. The result was a sharp division between conquerors and the conquered. The Spanish village ditch irrigation culture tended to become more isolated, more withdrawn, more determined to hold what they had. The newcomers, plus many Spaniards whose lives were more influenced by commerce, the professions, and government, looked to quite a different pattern for developing the water resources of New Mexico.

Another outstanding difference in cultural patterns which affected the control of water was that Spanish and Indian farmers were essentially subsistence farmers, while the incoming Americans brought with them a tradition of commercial agriculture. American agriculture was on a much larger scale, employed considerable capital, and thus ultimately needed to develop vast amounts of water to satisfy its needs. In addition, the American was not satisfied with the quiet, isolated life, so much a part of Spanish New Mexico, for his culture was expansive and mobile. Finally, the American federal government had established the concept of federal responsibility for most national internal improvements, which included water ways, flood control, and ultimately irrigation systems in certain cases. Such government action was rare in Spanish New Mexico.

Despite the obvious desire on the part of many New Mexicans for change in 1846, factors beyond their control kept dynamic change from occurring. Transportation was lacking, and this in itself was a severe technical limitation. To bring about a revolution in applied technology concerning water control required heavy machinery which could only be had at great expense. What was brought into New Mexico came over the Santa Fe Trail by wagon or stage. Exploitation of the growing industrial and mechanical capability of the northeastern section of the United States had to await the coming of the railroad in 1880.

Between 1846 and 1880 the quest for water in New Mexico had two main courses, the continuation of the old ways in most of the smaller communities and in the Indian Pueblos, and a new set of forces which prepared New Mexico for the spectacular developments following 1880. These new forces set some patterns which have since become normal operating procedures. Ditch irrigation remained the most common area for applied technology, but several new developments and concepts were added. Bored wells (as opposed to hand-dug wells) were first experimented with, and the use of artesian wells was widely discussed. There was an expansion of water-operated mechanical devices for grinding grains. Most significant was the need for water by the emerging mining industry of New Mexico and the technology developed to acquire that water.

There was a marked increase in the number, size, and value of farms in the decade 1850-1860 and, consequently, an expansion of irrigation facilities. The census report of 1860, however, shows that there was a decrease in the total acreage of improved lands. There was also evidence of fencing of agricultural land beginning in the decade of the 1850's which was directly related to American occupation.[94] Irrigation was also extended to new areas as a result of American occupation. The United States Army built forts as bastions against hostile Indians, and around those forts there frequently appeared irrigation systems in connection with agricultural production to supply the soldiers with food.[95] American civilians entering the territory sought lands suitable for agriculture, and since many of the lands in the Rio Grande Valley and its tributaries were already occupied, they were forced to seek other areas with available surface water. The first settlers in the valley of the Rio Hondo and the Rio Penasco in the Pecos drainage can be traced to this period.[96] There was also a concerted effort by the federal government to bring irrigation techniques to the Apache Indians in several regions, although it was not successful.[97]

The most significant development in terms of irrigation practices and policy was the attempt to develop an irrigation district with government funds for the Navajo and Mescalero Indians at Bosque Redondo, near Fort Sumner, on the Pecos river.[98] The first organized and well-financed effort at irrigation in the Pecos Valley occurred in conjunction with the Bosque Redondo Indian Reservation. This reservation, embracing an area forty miles square around Fort Sumner, New Mexico, was set aside for the Mescalero Apache in 1864. Subsequent to 1864, efforts were made to settle not only the Mescalero, but also numbers of Navajo at Bosque Redondo. The Pecos was dammed and diversion channels were built, as were irrigation canals. It was, for New Mexico, a massive technical effort. It was hoped that the Indians brought to settle this land would take up the ways of the white man and that a substantial agricultural development would result. The whole project failed for a number of reasons. The Indians were not knowledgeable in the ways of ditch irrigation and did not have the supervision by those who were. Also, the amount of water stored and diverted was not adequate for successful operation. Methods of stream measurement and detailed knowledge regarding surface water runoff were not well enough advanced at this time for adequate planning. Finally, floods, also little understood, and which tended to come at the peak of the growing season, washed out the dams and the diversion facilities, ending all hope of success. The entire Bosque Redondo experiment was abondoned.[99] It was an important experiment in government construction of irrigation facilities which laid the groundwork for future efforts. It was not the concept that was at fault, but rather lack of scientific information and insufficient technology. These shortcomings were solved in the twentieth century and the concept applied at Bosque Redondo became a contributing factor for massive entry of the federal government into water resource development and in water control.

In other regions of the territory early efforts to develop and utilize water showed the general expansion of water control beyond the narrow limits of Spanish and Indian efforts. In the area of Hot Springs (modern Truth or Consequences) there were efforts in the late 1870's to bring some irrigation. James Davis was named Indian Agent in 1876 and immediately moved to improve the food supplies of the Apache in the vicinity. In 1877 he induced the Apache to construct ditches to begin farming.[100] The oldest recorded irrigation canal in the area of Santa Rita in southwestern New Mexico was in the upper Mimbres Valley at San Lorenzo in 1869.[101] Early agricultural occupation in the Mimbres dates to the early parts of the nineteenth century when farmers were brought in from Chihuahua to grow food crops for the miners at Santa Rita. It is possible that some irrigation was in use then but there is no record.[102] These early settlers were driven out by hostile Apaches. The first permanent agricultural population came in the early 1850's, and there was rapid growth in the 1870's with the rise of mining in this part of New Mexico.[103]

Wells as a supplement for more traditional ditch irrigation were first introduced into New Mexico in the period 1846-1880. The hand dug well had been a part of the scene for a long time, but it was used primarily for domestic or stock water. The amount of water supplied by this simple technique was rarely sufficient for crop production. Increasing needs for water for crops brought interest in artesian wells. Artesian wells were known to exist in parts of Europe and in parts of the eastern United States, and produced large quantities of water. The problem was that they were usually deep and required considerable technology in drilling equipment to reach the water. There was much discussion in government reports about artesian wells which encouraged efforts to locate artesian waters.[104] Over a two year period in 1856-1860, a well was bored near Galisteo, New Mexico, as an experiment to see if artesian water could be reached. The well eventually reached a depth of 1300 feet. While free-flowing artesian water was not discovered, the well showed the practicality of wells as a source of large quantities of water, for water was evident in the well.[105] Pumping capacity was lacking, a problem that was not solved until near the end of the century. Thus the well, which, like the acequia, is so much a part of the quest for water in New Mexico, was first introduced.

Probably the major applications of technology to water development prior to 1880 were done by the infant mining industry in New Mexico. Two major efforts, one a complete failure, the other a moderate success, stand out as examples of the great lengths the placer gold miners went to get the water necessary for their operation. Unlike farmers, the miner could not locate his mine where the water was. If he was lucky, water was close at hand; if not, he had to apply whatever technology was necessary to get it.

The first gold rush in the far west was to Dolores Gulch, a few miles southeast of Santa Fe, in 1828, twenty-one years before the famous discoveries in California. Ten years later another strike was made nearby. The "Old Placers" with Dolores as the main camp and the "New Placers" with the town of Tuerto as the trade center had one thing in common: both lacked water with which to wash the gravels for the elusive yellow metal. The few springs in the vicinity supplied some, but the cost of hauling was high. In the winter the miners relied upon melted snow. Wells were dug, but the water table was much too deep to be reached by hand dug wells. In an effort to increase production in the gold fields, a company was formed to build a series of ditches and pipelines from the Pecos River across a range of hills to the east. The water was to be used for placer mining and for irrigation. The Pecos and Placer Mining and Ditch Company spent nearly $800,000 before giving up on the project. The engineering problems were simply too great and the technology too little for such a project to succeed at that time.[106]

In 1868, one of the few spectacular gold rushes in New Mexico mining history brought thousands of miners into the remote heart of the Sangre de Cristo mountains of northeastern New Mexico. Elizabethtown (of which nothing remains today) grew out of the discoveries on Baldy Mountain. Water for washing the gravel was a major problem facing the miners working the gulches. Tom Lowthian brought water in a ditch to his claim in Grouse Gulch. The Michigan Company and the Spanish Bar miners ditched off from the Moreno River and Comanche Creek. But still there was not nearly enough water to handle the volume of gravel being worked as the population increased rapidly in 1868. The largest flowing stream near Baldy Mountain was the Red River, which lay to the west across the mountain passes. A decision was made to dig a ditch from the Red River into the Moreno Valley to supply adequate water for the miners. Work began on the ditch on May 12, 1868. As many as 420 men were employed at the peak of construction. This amounted to nearly half of the able-bodied men living in the region. The first water was delivered to Martin and Scott's claim in Humbug Gulch on July 9, 1869. The ditch was slightly over forty-one miles long, and it had over three miles of aqueducts and side hill flumes (all made of wood). One aqueduct was over 2000 feet long and 79 feet above the valley floor at its center. The width of the ditch varied from 2.5 feet to 4 feet at the bottom, and from 5.5 feet to 7 feet at the top. It was two feet deep. Five miles of the ditch had to be blasted out of solid rock, at one place to a depth of 10 feet. The actual distance between the head of the ditch on the Red River and Grouse Gulch in Moreno Valley was only eleven miles, yet it took a difficult, circuitous route of 41 miles to deliver the water. The ditch cost $210,000, which, incidentally, came mostly from enthusiastic New York investors.[107]

There is no doubt that the ditch was at least partially successful. Nearly $2 million in gold was mined by water conveyed by the "Big Ditch" as it was fondly called. Yet it did not accomplish what it was intended to. It was designed to deliver 600 miners inches of water (about 1050 gallons per minute) to the Moreno Valley, and during the years of use much more than that was fed into the ditch from the Red River. In its best days it never delivered more than a hundred miners inches at the Moreno Valley end. Seepage, poor engineering, evaporation, inadequate bracing of flumes, and constant other problems caused the original company to fail. It passed through several hands and finally into disuse. The <u>New Mexico Miner</u> of June, 1900, carried the epitaph to the "Big Ditch:"

> The Lynch Ditch, which carries the water from the Red River to the Moreno placer mines at Elizabethtown is to be sold next month at a sheriffs sale to satisfy a judgement and cost aggregating $7,000.[108]

The function of grinding grains or corn into useable flour was a household function during most of the Indian and Spanish periods. Farming was subsistence level and a family function. With the advent of commercial agriculture in New Mexico, the function of grinding also became commercialized. By and large, the power source for the gristmill was water power.

To utilize running water required a special use of ditch technology and, of course, knowledge of the mechanical devices which converted the power of the running water to grinding of grain. An early example of this kind of technology is the Cordova Grist Mill located on the Rio Pueblo, between Mora and Taos, New Mexico. It was constructed in 1860. Water was diverted by a simple dirt diversion into a ditch which carried the water to the mill. The wheel was horizontal and was attached to a shaft exiting upward which in turn was fixed to a stone. A second stone was laid on top of the powered stone and thus was achieved the grinding action. The stones were cut from lava flows near Dixon, New Mexico. The mill is still in operation at the present time, although not a commercial venture.[109] One could find any number of such mills across New Mexico during the nineteenth century. Few of them exist today, and few records of their operation remain. One historic mill was located at Socorro, New Mexico, in the 1880's and 1890's. The mill utilized water brought from a spring in a ditch.[110]

The most important developments during the period 1846-1880 related to the quest for water by miners in New Mexico and to the first efforts to bore deep wells. Important ideas for the future were inherent in federal government activities to plan and construct the irrigation system at Bosque Redondo. The old methodology and the old social system remained essentially intact. These traditional things existed in close proximity to the new forces which were harbingers of change, such as mining, commercial agriculture, new values and standards in law, land ownership, and water rights. Yet the old was persistent and resisted change. Despite the resistance of traditonal methodology, by 1880 vast numbers of New Mexicans, mostly newcomers, were prepared for a rapid acceleration in the quest for water.

THE QUEST FOR WATER BECOMES A CRUSADE

1880-1900

Two things influenced the quest for water more than anything else during the final two decades of the nineteenth century. Overshadowing all other influences was the coming of the railroad to New Mexico. This initiated a boom in all areas of New Mexico's growth, unparalleled before or after. The Santa Fe Railroad reached Albuquerque in 1880, and quickly built south through Socorro, San Marcial, Hatch, and finally, on March 10, 1881, Deming, where the Santa Fe joined the Southern Pacific building east from California. New Mexico was thus tied to the rest of the nation through the trans-continental rail system. Later in the decade the Santa Fe built its own line from Belen to the west coast, and the Southern Pacific continued east to El Paso and on to New Orleans, giving New Mexico two links in the trans-continental system. In the early 1880's the Denver and Rio Grande Western Railroad entered New Mexico from Colorado with narrow gauge tracks which came first to Chama and eventually to Santa Fe. In the early 1890's, the Rock Island joined with the El Paso and Northeast Railroad (a subsidiary of the Southern Pacific) which ran north from El Paso through Carrizozo and Tucumcari, thence over the Rock Island tracks into the trans-continental system. These final links gave most regions of New Mexico rail service and broke the age old isolation which had so hindered its growth.[111]

The second important factor, which can in part be attributed to the growth of railroads, was a rapid population growth. The population of New Mexico in 1880 was just over 100,000. The official census of 1890 gave the population as 153,076, though most local observers felt the real population to be nearer 185,000. The ethnic make-up of the people also changed during the 1880's and 1890's. Immigration became increasingly American as opposed to Mexican, and after 1880 the number of people coming from parts of the United States became the dominant feature of population growth. In many areas where the Spanish-Americans or Mexican-Americans were in the majority prior to 1880, the same groups became a minority by the turn of the century. This growth gave New Mexico expanded capabilities in terms of labor supply, capital, higher levels of business activity, transportation, and technology.[112]

The pulse quickened with the advent of the railroad age, and in the major population centers, in the mining camps, and in areas suitable for commercial agriculture, the Americanization of New Mexico began to take place. Interestingly enough, little changed in the ditch irrigation culture in northern New Mexico or in the Indian pueblos. They retained the old methods and found no advantage in the new technology.

Irrigated agriculture expanded rapidly in the 1880's, and particularly after 1890. There was a decline in the cattle industry in the middle 1880's which forced many people to find more suitable use of their lands. This trend became apparent when comparisons were made between the early part of the decade and the end of the decade. In 1882 there were no irrigation works in New Mexico built on solid engineering principles, and few companies engaged in developmental work.[113] By 1888 investors were turning from ranching to the rapidly developing irrigation companies being formed. In New Mexico there were 19 irrigation companies incorporated in 1888; 32 in 1889; 23 in 1890; and 14 in 1891--a total of 88.[114] It was estimated that 40 percent of the land brought under irrigation during the decade of the 1890's was by these companies. The Springer Land Association purchased 130,000 acres from the Maxwell Land Grant Company, most of it for irrigation development. The Maxwell Land Grant Company initiated work on its Vermijo Ditch project in 1888.[115] Other areas of successful development were along the Pecos River, Rio Grande, San Juan, and in the Mimbres Valley.[116] The Bluewater-Grants area underwent its first development in these years,[117] as did the Tularosa Basin.[118] Irrigation was begun in the Carlsbad area by private interests in 1888.[119] Some counties chose areas that were impractical for irrigation and the developments failed. One of these was in Tijeras Canyon east of Albuquerque, and another along the Rio Puerco.[120]

In Santa Fe, in anticipation of the railroad and therefore rapid population growth, a stone dam was built on the Santa Fe River in 1881. It created a reservoir which held 35 acre feet of water, and was connected to a distribution system by a 10-inch wooden pipe line. Water was both for domestic use and for irrigation. Sediments quickly filled the reservoir, and in 1894 a higher dam, Twomile, was built with a 406 acre foot capacity. A channel was constructed along one side of the reservoir to carry off sediment laden flows during flood stage.[121] In 1895 a hydroelectric plant was constructed which used water from Twomile dam. Santa Fe, the capital city of the Spaniards, kept pace.

Development in the middle Rio Grande Valley progressed slowly, but the groundwork was laid for the building of Elephant Butte reservoir and its supporting irrigation works and hydroelectric power plant in the twentieth century. Increasing use of Rio Grande waters in New Mexico, and the proposal that a dam be constructed to allow further expansion of irrigation in the broad valley area in southern New Mexico, brought continuous protests from Mexico, also a user of Rio Grande waters. In 1895 Mexico issued a sharp protest concerning immodest use of Rio Grande waters by New Mexicans and irrigators in Colorado. This resulted in the appointment of an international commission to decide on equitable distribution of the water.[122] It took thirty years before these early plans bore fruit with the construction of Elephant Butte Dam.

The most exciting irrigation story in New Mexico during the final decade of the century was in the Pecos Valley, specifically the area now known as the Roswell Artesian Basin. The effort at Bosque Redondo in 1864 had failed, but the dream of a great irrigation system utilizing the waters of the Pecos River did not die. Following American occupation of New Mexico in 1846, an ever-increasing number of cattle and sheepmen began to use the rich grasses of the Pecos Valley. This growth reached its peak in the years following the American Civil War. By the mid 1870's, however, power in the area began to accrue to the growing numbers of commercially oriented people (bankers, store-keepers, land speculators) at the expense of the livestock interests. Numbers of people living in the region means more to the commercial interests than numbers of cattle. In the minds of some of these men appeared a vision of great areas of irrigated crops, tilled by farmers who flocked into the valley in great numbers from all over the world. All that was needed was an extensive irrigation system to spread the waters of the Pecos out on the lands bordering the river.[123]

While many men were eventually involved in bringing this dream to reality, three names stand out. One of the first to visualize the possibilities for extensive use of Pecos River surface waters was Pat Garrett, already famous for the slaying of Billy the Kid.[124] He in turn interested Charles B. Eddy, a rancher, in the project. Eddy brought the most important man in in the early development of the Pecos Valley into the story, James J. Hagerman.[125] While good promoters, neither Garrett nor Eddy had the financial connections or the managerial ability to make a project with such broad impliclations work. The extensive plans included the following construction projects: The Hondo Reservoir, southeast of Roswell; the northern canal starting near Roswell and running south to the Hagerman District; the Eddy (Avalon) dam and reservoir; the southwestern canal starting at the Eddy dam and running south on the west side of the Pecos; the southeastern canal starting at Eddy dam and running down the east side of the river; plus a large system of ditches in Texas. The consultants (geologists and engineers) led the developers to believe that the natural flow of the Pecos River, coupled with the small amount of storage at Eddy Lake, would meet requirements. The minimum flow had been estimated at 1000 cubic feet per minute, while actual minimums did not exceed 100 feet per minute. Great expense was incurred when additional storage facilities had to be constructed to correct this mistake.[126]

The key figure who carried through much of the work was James J. Hagerman. The early Pecos Irrigation and Investment Company was reorganized into the Pecos Irrigation and Improvement Company in which Hagerman was the guiding force and the primary source of capital. Garrett and Eddy assumed secondary roles. The northern canal, the Eddy dam, and considerable other ditch construction was complete by 1891. Also, by that time, some work had been done on the Texas canal and the Hondo reservoir. The Pecos Valley Railroad brought its tracks into Eddy (Carlsbad) in December, 1890 (this railroad was built by J.J. Hagerman). The dreams of Garrett, Eddy, and Hagerman were beginning to come true. The railroad was continued to Roswell in 1894, and in 1898 was continued to Amarillo, Texas. Settlers were brought in from many parts of the United States and from Europe to settle on lands watered by the Pecos River.[127]

Disaster struck in the early 1890's, however. The financial panic of 1893 dried up sources of financial support. Hagerman's personal finances suffered serious setbacks as much of his wealth came from silver mining and railroads serving the mining districts in Colorado. Also, in 1893, floods washed out the storage dams on the Pecos River, forcing expensive reconstruction. Then, too, there was the chronic problem of over-appropriation of water. The surface flow simply could not supply enough water for the numbers of people to farm lands adjacent to the river.[124] By 1906 the entire project was financially bankrupt and the assets of the private company were sold to the newly created Federal Reclamation Service for $150,454.55. (Hagerman alone had invested $1,800,000 in the irrigation project.)

Even before 1890, it was apparent to all concerned that the supply of water was not adequate to supply the agricultural, commercial, and domestic needs of the Pecos Valley. If the area was to continue to grow, and if the massive technological effort was to survive, and if the investment already made was to be protected, additional water resources had to be developed. In short, to an already substantial investment in technology, a much greater investment had to be made. Fortunately for Hagerman, the railroad serving the Pecos Valley was successful and he made back all he lost on the irrigation system, and more.

By the late nineteenth century, geologists and hydrologists had made sufficient gains in knowledge concerning groundwater to be aware of the potentialities of an obvious artesian basin in the middle area of the Pecos. American technology, usually up to the task, had developed well drilling techniques and equipment (mostly in early oil field development) capable of sinking wells deep enough to tap these aquifers. The second phase of the irrigation story in the Pecos Valley began when the city of Roswell drilled the first artesian well in 1891.[129] But the bulk of that story is part of the twentieth century and must be told in that context.

The Roswell basin was not the only area where the development of drilled or bored wells took place as the century closed. Wells for domestic and stock use appeared in the Carlsbad area before 1900.[130] In 1896, in the Rincon and Mesilla Valleys, near modern Las Cruces, pumping of groundwater was practiced by a farmer named Shiller who irrigated 800 acres by well. His land had been under the Dona Ana Ditch prior to his drilling of the well.[131] The first well drilled in the Playas Valley of far southwestern New Mexico was drilled in 1899. It was 4 inches in diameter, 98 feet deep, and was located at Ojo de las Cienegas.[132] At Shalam, New Mexico, founded by a religious group, "eight windmills pumped water into railroad tanks and pipes carried water to all buildings, barns, corrals and feed pens."[133] The village also had an irrigation reservoir which held 17,000 gallons. A huge stone well with a 60 horsepower boiler and pumps supplied the reservoir. Sixteen miles of pipes carried the water to the canals when the river was dry.[134]

The effect of improved capital investment, the growth of companies which organized large scale irrigation systems, the intensity of commercial agriculture as a concept, and the rapid growth of technology (including the railroad), gave to New Mexicans the basis upon which to build significant water control systems. In addition, it brought into New Mexico whole new concepts in science and technology which gradually filtered down to small farmers and ranchers who applied these new ideas in their own makeshift, trial-and-error way in their search for water. Despite the advances made, little effect was seen on the old village irrigation systems in northern New Mexico or in the Indian pueblos. A century of change had passed them by, or, perhaps, had been rejected by them.

THE QUEST FOR WATER IN THE EARLY TWENTIETH CENTURY

1900-1945

The final twenty years of the nineteenth century brought with them in New Mexico the much needed scientific principles and the accompanying technology to initiate a wholly new set of concepts and policies in terms of water resource development. During the first half of the twentieth century these patterns were rapidly advanced by massive doses of capital investment, both public and private. Could technical application somehow be quantitatively measured, it would probably show that a significantly high percentage of the total occurred after 1900.

To fully understand water resource development in New Mexico in the years 1900 to the end of World War II, it is first necessary to understand the unique water law that evolved, first in the territory, then in the State. As early as 1851 it was apparent that water law in New Mexico was to differ essentially from the common law "Riparian Rights" which traditionally dominated water law in the United States. The areas in New Mexico which had been influenced by Indian and then Spanish-Mexican irrigation had applied the concept of public control of water and community ownership of ditches. Surface water use was based upon "prior right" (of use) or "prior appropriation." The territorial legislature in 1851-1852 declared that ditches or acequias already established should not be disturbed; that all rivers and streams theretofore known as public ditches were officially declared to be such.[135] Legislation continued under territorial law to expand this idea, and eventually arrived at a comprehensive surface water law in 1907. This law included the basic idea of prior appropriation and established the Territorial Engineer as the administering officer of the new law. His duties included licensing procedures for application of water for new uses, changed uses, for maximum amounts to be diverted, the transfer of rights, for procedures in the adjudication of rights, and for their forfeiture for non-use. This legislation was incorporated into the New Mexico State Constitution in 1912 and remains the basic surface water law for New Mexico today.[136]

Ground water law did not lag far behind in its development. In 1927, because of the extensive application of technology and capital to well-drilling, and because of the development of deep artesian wells, New Mexico passed a statute effecting the administration of law regarding ground water use. Again the doctrine of prior appropriation dominated legislative intent. The law provided that the waters of underground streams, channels, artesian basins, reservoirs, or lakes having reasonably ascertainable boundaries belong to the public and are subject to appropriation. The State Engineer was named to administer the law, and had supervisory powers over such things as the apportionment of waters, the creation of new water districts, establishment of groundwater basins, and hydrographic surveys.[137] While the basic law was found unconstitutional on technical grounds, it was corrected and became law in 1931. Later legislatures made adjustments and refinements in both the 1907 and the 1931 laws, but only to bring them into line with advancing needs. These two significant legal landmarks remain the basic water laws of the State.

New Mexico, while not the first state to enact ground water legislation, nonetheless pioneered in this field, and its laws have set the pattern for much of the subsequent water law development in the American West. The key thing about New Mexico water law is that prior appropriation is the basis, not riparian right. The riparian doctrine has been consistently rejected in New Mexico.

With the availability of adequate technology and a rapidly developing federal and State water policy, water control in New Mexico went ahead at a rapid pace. As news of the first drilled irrigations wells spread after 1900, a number of formal studies were quickly initiated to search out suitable subsurface water sources. Many of these studies were undertaken by private companies or individuals who sought to take advantage of the economic opportunity offered. Some efforts were carried out by hydrologists using traditional methods, others by drillers actually putting down experimental wells. Early development in the San Simon Valley was a good example of privately financed irrigation using groundwater, as were those around Las Vegas.[138] State controls and State sponsored investigations also played a major role in expanding the use of underground waters. Water systems around Deming were brought under State control by the State Engineer as a declared basin. The Pecos Valley, in its lower reaches, was similarly treated.[139] The federal government contributed considerable data to the total accumulation of information. Through the United States Geological Survey and the newly created Bureau of Reclamation, a steady flow of information regarding ground water and wells was published and made available to promoters of ground water irrigation.

In contrast to the rapidly expanded knowledge of the science of hydrology, ground water, and accurate information on surface flow was the primitive irrigation technology practiced in many of the older parts of the State. For example, at Jemez, ditches dating to before the coming of the Spanish were still in use in 1911: the only apparent improvement was the use of wooden flumes.[140] At Santa Ana, jettys to protect ditches and aid in diversion were simple wooden piles, insecurely anchored, wired together, and filled with brush, as reported in 1915.[141] Indian irrigation systems remained much as they had been for centuries. The same could be said for the Spanish village systems. They remained crude, inefficient, and did not reflect the growing technical and scientific knowledge available in New Mexico.

Irrigation in the first 20 years of the century followed the wide variety of patterns already established. Surface waters were largely appropriated, although much was lost by runoff because of limited storage facilities. Irrigation using subsurface water made some progress, however, and technology now allowed the drilling of numerous shallow wells which produced enough water for small-scale irrigation. The areas of most active drilling were the Pecos Valley, in the Portales area, and the Mimbres Valley of southwestern New Mexico.[142] A typical well of this period was 6 to 8 inches in diameter, 200 to 270 feet deep, and cost about 50 to 75 cents per foot. It had standard casing, and a large producer flowed about 100,000 gallons per day.[143] Machinery for pumping enough water from these shallow wells for large scale irrigation was not yet available during most of the period. A report in 1913 showed only two out of 100 wells in the Playas Valley were equiped with adequate pumps. Windmills were most commonly used, but sometimes small, inexpensive gasoline engines supplied power for pumps.[144] The pumping problem was pressing, and considerable effort was expended to develop the technology to improve pumping capacity. This was also true of drilling techniques.[145] While important advances were made, they were not generally put into massive use until after World War II.

An example of the growth pattern established in these years took place in the Portales Valley of eastern New Mexico. In 1910 about 4000 acre feet of water was pumped onto less than 2000 acres of land under cultivation. By 1929, 166 pumping plants were irrigating 5000 acres of land; in 1931, 300 wells irrigated 9000 acres of land; and in 1953, 1000 wells pumped 101,000 acre feet of water onto 49,000 acres of land.[146]

In areas with ample water, surface or underground, as irrigation systems grew and prospered they tended to grow together, creating networks of wells, diversions, and drainage systems. Growth created problems such as silting, maintenance, soil saturation from rising water tables, and others, all of which required more and more technology in their solution. A prime example was in the Rio Grande Valley. As early as 1890 drainage districts were attempted.[147] Also, the need for a storage reservoir to control floods for irrigation, and for silt control of the Rio Grande, was discussed before the turn of the century. In 1903 serious planning began, and in 1910 the Engle Dam was proposed at the Elephant Butte site. The dam was to be rubble construction, 265 feet high, 1400 feet long, and was to irrigate 40,000 acres. It was to have a storage capacity of 2,538,000 acre feet, which would have made it the largest in the world at that time. Construction was to be by a private irrigation company. Constant problems with early construction, financial pressures, and mismanagement caused the whole project to be turned over to the Bureau of Reclamation which continued the planning and eventually built Elephant Butte Dam with its irrigation system and electric generating plant. The dam was a straight gravity flow structure of cyclopean concrete, with a length of about 1200 feet. Its height, from the lowest foundation to the roadway, was about 300 feet, over 90 feet of which was below the river bed. The top width was 20 feet. A railroad was constructed, eleven miles long, from the dam site to Engle on the Albuquerque to El Paso line of the Santa Fe railroad to bring in materials and supplies. The cost of the dam was five million dollars. The subsequent building of canals and laterals for irrigation, other smaller dams and diversions, as well as the facilities for production of electricity, made the Elephant Butte Irrigation System the finest in the world.[148] It set patterns for future developments in New Mexico and ushered in the epoch of large-scale federal expenditures in the development of water resources in New Mexico.

The Pecos River continued to be an area of important water control in the early years of the century. Private interests had made initial efforts at developing the surface water potential. The Avalon Dam and the McMillan Dam were constructed to store water of the Pecos, in hopes of balancing the insufficient flow during parts of the growing season. In 1904 the Avalon Dam was washed out in a flood and the McMillan was badly damaged. The result was the end of the Pecos Irrigation Company. In 1906 the entire project was turned over to the Bureau of Reclamation for revitalizing. The Avalon and McMillan Dams were reconstructed and enlarged, as were most of the other irrigation works in the system.[149] The Carlsbad Irrigation Project, as this phase of Pecos development was called, is another prime example of the growing influence of the federal government. Continued population and industrial growth in the Pecos, with accompanying demands for water, led to the construction of another earth-fill dam and large reservoir--the Alamogordo Reservoir--in 1937.[150]

On a lesser scale this pattern of dam and reservoir construction was apparent across New Mexico. The Bluewater Dam, on Bluewater Creek, west of Grants, was first built in 1894. It was a low earthen dam which created a reservoir holding about 20,000 acre feet of water.[151] The original dam and a second similar dam were continually washed out. In 1927 the Bluewater-Toltec Irrigation District was formed, and the present 80 foot dam storing 45,000 acre feet of water was constructed. Canals were built to service 10,647 acres, but the watershed never provided enough water for the project and the acreage was reduced to 5,488 acres.[152]

In northeastern New Mexico the Conchas Dam-Tucumcari Irrigation Project was initiated in 1935. This dam and reservoir complex was a multipurpose project having the functions of flood control, irrigation, and recreation. The completion of the dam, supporting canals and laterals, recreational facilities, and flood controls took until 1949. It included 116 miles of main canal, 200 miles of laterals, and irrigated 45,000 acres. Growing knowledge of stream flow and sediment retention led to division of the reservoir into separate levels for sediment storage and recreation, detention storage for flood control, and irrigation storage.[153]

Thus the story of New Mexico's quest for water in the first fifty years of the twentieth century was largely one of the federal construction of large scale irrigation projects, flood control, and recreation facilities. Private efforts had failed, except in small scale projects. The story remained primarily one of surface water use supplemented with some wells tapping subsurface aquifers. It involved the building of huge storage facilities that served the purpose of holding excess floodwaters until they were needed. This great, emerging system of dams and reservoirs stands out as one of the strong themes of New Mexico water history, along with the village irrigation systems of the Spanish and Indian villages.

While wells expanded rapidly during the period, the available technology restricted their use. The windmill was the primary power source for raising water, and because of the severe limitation on volume, the water was mostly used for domestic and stock use, or for very small gardens. Wells, and power sources to pump large amounts of water from deep aquifers, came into great prominence after World War II.

THE QUEST FOR WATER SINCE WORLD WAR II

The technical emphasis in the quest for water in New Mexico in the period following World War II was in the development of ground water resources. Advances in irrigation, use of water by the mining industry, and even flood control tended to have a direct relationship to the number of wells being drilled and the amount of technology being applied. While earlier periods were concerned with the gradual, total appropriation of surface water, the modern period is the story of the over-appropriation of ground water resources.

Following World War II development of surface water resources seemed to be at a standstill. The basic systems for water diversion which had been devised by New Mexicans in the small villages at very early dates were still in use.[154] Ditch and embankment systems were not developed beyond the addition of siphon tubes and a few sprinkler systems.[155] Simple as these two additions were, they provided a considerable advancement in village irrigation techniques. Dam and reservoir construction continued to be of importance, but little additional land could be brought under cultivation by further development of surface water for it was all appropriated. If New Mexico was to increase her water for any use, it had to come from subsurface sources.

The frequency with which wells were drilled during the late 1940's and the early 1950's makes it difficult to discuss all areas affected. The primary areas of well development came in areas where there had been early experiments and investigation of groundwater resources. These areas included Roswell, Carlsbad, Artesia (in other words, the Pecos Valley), around Deming, and other select areas of southwestern New Mexico, in the Rio Grande Valley (mostly to supplement surface water), and in isolated valleys in northern New Mexico, such as the Grants-Bluewater area.[156] In almost all cases wells were initially drilled to supplement growing shortages of surface water.

The majority of the large wells drilled following World War II were developed for irrigation purposes and for city or village domestic water supplies. By the mid-1950's over a million acres of land were under irrigation in New Mexico, of which 52 percent received water solely from pump irrigation and another 14 percent used ground water with some surface water assistance.[157]

Use of ground water continued to grow and increased 20 percent between 1950 and 1960. In comparison, surface water irrigation remained stagnant to 1960 and then decreased rapidly.[158]

Most of the wells developed during these years were equipped with cylinder pumps and were powered by electricity, in contrast to the more typical windmills of earlier days.[159] Improvement in pumping power led to efforts to improve drilling techniques which could drill larger and deeper wells. Steel casing and powerful drilling rigs which had been developed in the oil fields of the West were diverted to water resource development .

An area that developed rapidly after World War II and was fairly typical was in the Playas Valley of southwestern New Mexico. Average wells prior to the war were 100 to 150 feet deep, and most of these were deepened or replaced by wells ranging down to 500 feet. Between 1948 and 1954 the number of wells increased from about 40 to more than 120, and the irrigated acreage increased from nearly 4000 acres to 11,400.[160] This development was concentrated in a very small area. In one area with a two mile radius there were 64 wells operating at one time. This represented 39 percent of the total number of wells in the region.[161]

This same pattern was in evidence all over New Mexico. Very quickly it became apparent that controls had to be applied as ground water levels began to drop as more and more was appropriated. Both the State and federal governments began extensive measurement programs to determine use capability of any given ground water basin. This required more technology and new theories of ground water science, and a vast array of technical devices were developed to measure wells. The rapid growth of the science of hydrology as a separate field went hand in hand with this. The assimilated data from the well measurement tests were utilized by the hydrologists to formulate theories of underground aquifers. Despite all of the effort, the science, and the controls, it became evident by the middle-1960's that much of the State's underground water sources were being over-used and serious water shortages were appearing, or underground waters were becoming brackish and unsuitable for irrigation without treatment.[162]

Irrigation, utilizing both surface and underground water, was a primary concern during the post war years, but it was not the only concern. Most effort, and a large percentage of total money spent, was on irrigation.

One area of water development seldom written about and not well documented was for use by livestock. Probably the number of wells for livestock use made up a majority of the total wells in the State. The amount of water produced by these wells made up only a small fraction of the total water produced.[163] The rancher and small water user, both outside the boundaries of the large development projects, used a variety of techniques, often based upon trial and error and upon "home-made technology." They showed a great deal of ingenuity, and in some cases considerable knowledge of engineering and mechanical skills, despite the fact that they had little formal training in these areas. They went to great lengths to get the water that was necessary to their livestock operation. Frequently one can read much of the history of the types of technology applied by the ranchers by visiting field sites, and often from a single site. West of Datil, New Mexico, just south of Highway 60, is a well and watering site which shows many generations of technology, all within a few yards of each other. The old windmill tower, probably constructed around the turn of the century, still is in use. The mill has fallen off and lies nearby. On the tower are two generations of pumping devices: an old one-cylinder gasoline engine, probably dating to the early 1930's, which is no longer serviceable; and a new electric pump which now draws water from this very old well. The water is carried from the tower across a narrow arroyo to watering tanks on a bench. The remains of the oldest tank, a simple earthen tank, can still be seen, but is no longer in use. On part of the earthen tank a stone masonry tank was constructed but is now crumbling and is mostly gone. Currently a galvanized steel tank is receiving the water and redistributing it through a system of plastic pipes to several watering tubs hundreds of yards from the well. The foundation of the new steel tank was made, at least in part, from the remains of the masonry tank.[164] Such sites can be found throughout the State. The technology applied by the rancher in his search for water is a remarkable story.

Although applied technology was most important in irrigation, both surface and underground water, and in the rancher's quest for water, there were other areas requiring unusual applications for the control of water. Water was always an essential element in mining and smelting operations. The mineral industries of New Mexico came of age in the twentieth century, entering their industrial age, thus requiring increased water supplies. The mass production of copper in the southwestern part of the State, potash in southeastern New Mexico, and uranium at Grants created vast new needs for ground water. The petroleum and natural gas industry, larger than all the rest of the mineral industries combined, added its demands. The system developed by the Chino Mines Division to supply water for its copper mines and flotation operation at Santa Rita and Hurley is an engineering marvel. Their water comes from two sources: from wells tapping a deep aquifer in the playas north of Deming, and from several deep mines which were abandoned and flooded. The water from these sources is pumped through pipe lines into a closed system at the flotation mill or to various other operations, such as leaching in the dumps, or for use at the smelter. The water from the flotation process, which requires large quantities of water, is recirculated through a complicated system of purifications and settling processes to bring it to the standard required for reuse. Many of the chemicals used in the process are also recirculated and reused.

An interesting sidelight of the layout of the Chino operation is directly tied to the evolution of water technology. The flotation mill is located at Hurley, New Mexico, 10 miles and 1500 feet lower in elevation than the open-pit mine at Santa Rita. Ore has to be dug, put on rail cars, and transported to the mill. The placement of the mill was determined, in 1910, because of the problem of pumping water in large enough quantities to operate the mill. American technology simply had not developed pumps with the capacity large enough to handle this kind of problem. Thus the mill was located where water was available.

The large-scale applications of capital which went into modern mining techniques placed a considerable emphasis upon the quest for water and were responsible for developing many areas of water control which had applications in other areas, such as pumping methods, purification technology, and pipeline development.[165]

Generally, the main source of water for community systems and domestic use was from subsurface sources. In 1950, approximately 83 percent of the municipal systems in New Mexico used wells. By 1955, the figure was 92 percent, and of 8 major cities that used surface water exclusively in 1950, 7 had drilled or were drilling wells by 1956.[166] Most communities in New Mexico rely upon ground water supplies for their domestic water.[167]

Another important source of community water was surface water, such as rivers, springs, or lakes. Taos Pueblo obtained its water supply from the Rio Pueblo de Taos.[168] The Animas River supplied the city of Aztec and the San Juan supplied the towns of Bloomfield and Shiprock.[169] Dulce depended upon the Navajo River and Las Vegas pumped from the Gallinas River.[170] A pump collection system drawing upon a series of springs was used at Northern New Mexico State School at El Rito.[171] Wagon Mound, in Mora County, depended upon a spring system with a catchment structure, as does Maxwell in Colfax County; Hatch, Seboyeta, Laguna Pueblo, Acoma Pueblo, Placitas, Jemez Springs, Cuba, and Cerrillos all depend on springs for community supplies.[172] The use of small streams or creeks for water supplies was illustrated by Red River which pumped its community water from Pioneer Creek.[173] Magdalena utilized a unique water source when it drew its water from the unused Ozark Mine at Kelly, New Mexico.[174] Water from the Navajo River was at one time hauled by wagon or truck to Lumberton, in Rio Arriba County.[175]

Storage of community water involved a variety of technical devices. These ranged from adapted natural catchment structures to complex man-made holding facilities. Probably the most famous natural catchments in New Mexico are the stone "pothole" reservoirs at Acoma.[176] The San Marcos arroyo is part of the natural catchment at Cerrillos.[177] Manmade storage facilities include an almost infinite array of reservoirs, and metal, stone, or concrete tanks, both private and public. Santa Fe stored its water supply in three reservoirs: one 126 million gallon open reservoir, one 223 million gallon open reservoir, and a 997 million gallon open reservoir, all three for raw water.[178] A 100 acre foot earthen and concrete reservoir was used for storage of water for Springer.[179]

Large steel storage tanks was the most widespread method of storing community water supplies. They came in all shapes and sizes. A 1,250,000 gallon covered steel tank served Dulce, New Mexico, while two tanks, collectively holding 5,500,000 gallons, served the town of Grants. Albuquerque had 30 covered concrete surface tanks with a capacity of 122,263,000 gallons.[180]

Smaller tanks, pressure of gravity-run, served small communities and private groups in the rural areas. Examples are the private wells and small tanks used at Hurley,[181] Los Ranchos de Albuquerque, Peno Blanca, and Cubera.[182]

Movement or distribution of water for community and domestic systems was accomplished by ditches and pipelines. The domestic supplies at Tularosa just a few years ago were chiefly from irrigation ditches. The public and railroad supplies at Alamogordo at one time were obtained from a system of ditches from several springs in Alamo Canyon. The water was brought through an iron pipe 10 to 18 inches in diameter to two city reservoirs. The general supply for Orogrande and other mining settlements in the Jarilla Mountains was derived from a pipeline which tapped the Sacramento River. The water first fed into a reservoir on the Sacramento and was then carried 25 miles by pipe to the Nannie Baird reservoir.[183] Surface water from Lake Maloya was piped to the Raton city reservoirs. While most of the pipelines were of steel or plastic pipe, the one at Cimmaron brought water through 16 miles of wooden pipe.[184] Generally, distribution of community water supplies through pipelines amounted to a few single-pipe systems in the rural areas, while Albuquerque and Las Cruces, and other major population centers, are served by modern, complex systems.

Evolution of community water systems and the resulting applications of technology show similar patterns as other areas of water control. The urban areas, or areas of fairly dense population, have applied the most modern kinds of technical devices and have benefited most from large-scale State and federal expenditures. The rural areas and small towns and villages lag far behind in these technical levels, and in most cases their water systems are relatively primitive.

The large amounts of saline water available in parts of New Mexico, partly from natural saline sources and partly from over-pumping and over-irrigation, led to considerable effort to purify saline waters. One of the important facilities in the United States for the conversion of saline water was built in the Pecos Valley. It converted a million gallons of brackish water per day, using a vapor compression technique. It served a practical purpose and was an important experimental facility.[185] In 1972 the original plant was to be replaced by a more modern facility, if federal funding became available.

In the 1950's and 1960's flood control began to play an important role in water control policy. Besides reservoirs designed to hold floodwater, such as Abiquiu Dam on the Chama, floodwater retarding structures such as levees and channels have been effectively used. Non-structural techniques such as floodplain management and flood forecasting have been important additions to water control knowledge.[186]

Water salvage, both in arid, waterless grazing regions and in the lusher valleys with water supplies, has been practiced in a variety of ways. Chaining, a method of clearing unwanted semi-desert vegetation, such as juniper and pinon trees, from grassland areas to increase soil moisture and promote the growth of grasses, has been attempted by federal and State agencies. Success has varied from little or none to moderate success.[187] Another technique employed by land management engineers is the application of phreatophyte vegetation control to salvage water in the valleys. This has been done primarily in terms of salt cedar and mesquite whose destruction, it was hoped, would cut water utilization by these species, thereby increasing available water for other purposes.[188] Only moderate success was reported.

All of the areas discussed in terms of the modern period represent areas of applied technology. The rapid growth of technical application since World War II was mainly in the area of ground water use. Improved drilling techniques, better pumps, adequate power sources, better means of transporting water, improved storage concepts, capability of building larger dams and reservoirs, and vast flood control systems, mostly planned and executed by federal and State government agencies, have made New Mexico one of the most heavily developed areas in the nation in terms of water technology.

OVERVIEW

The Indian in ancient New Mexico applied a significant percentage of his technical effort toward the control of water. He utilized very well what technology he had, and, while strictly limited to stone and without metallurgy of any kind, he created water control systems seemingly far beyond his cultural capability. As a result of the new studies of Indian water systems, we can now class many of the tribes of New Mexico not only as builders, potters, and farmers, but also as water engineers.

With the coming of the Spanish to New Mexico there was improvement in the water control systems. The Spanish had better tools, a more advanced knowledge of the principles of water flow and engineering techniques, and a law and social structure already geared to irrigated agriculture. Yet Spanish irrigation techniques in New Mexico were not so much superior to the Indians, despite their technical advantages. Certainly they never achieved the levels which were apparent in Mexico or in Spain. The explanation probably lies in the extreme isolation under which New Mexicans were forced to exist during the long years of Spanish colonial experience. This isolation and the long distances from New Mexico to the nearest centers of Spanish authority and influence meant that transportation was nearly impossible, ideas slow to come, and that there was little chance of a stady flow of new immigrants who might have brought with them more advanced techniques. And, of course, always a factor was the extreme poverty of the province, making capital acquisition difficult. Advances in water control capacity increased during the Spanish period but not up to the potentials of Spanish culture.

When New Mexico became a part of the United States in 1848 and as American influence became more and more dominant, significant changes began to appear. The most significant change during the period 1848-1880 was a gradual shift from subsistence to commercial agriculture--a shift that brought with it an increasing demand for larger and larger quantities of water. These Americans, committed to the idea that technology could solve most problems, were eager to bring maximum levels to bear. The limiting factor during these years was transportation. Until 1880 any machinery brought into New Mexico had to come by wagon over the Santa Fe Trail, a difficult process.

The theme quickened after the Santa Fe Railroad built into New Mexico in 1880, and subsequent roads connected the territory to the rest of the nation. The result was the rapid exploitation of available surface water resources. This was followed quickly by exploitation of ground water as drilling techniques and technology made possible deeper and bigger wells. Storage facilities for irrigation waters followed, and in quick succession came drainage projects, flood control, more dams and reservoirs, even movement of water through complex systems of diversions, tunnels, dams and lakes from basin to basin and from state to state. In short, there was a massive technical application, utilizing every possible device toward water control.

The technical level and the impact of the major water projects in New Mexico were fairly well documented and easy to measure and to understand. More difficult, however, was that technology applied by the village irrigator, the small and medium ranch operation, and the small mining operations across the State, now and in the past. The small-scale applications were hard to trace, and heavy reliance was placed upon visual observations and photographs, for almost no records exist. There was and is an amazing ingenuity shown by people with little or no technical training to somehow bring water from the arid land of New Mexico and to build sound, although not rich, economic and social systems at the local level. Their attitudes about water and the technology utilized to develop it, or to move it where it was needed, have added much to the evolution of collective political and legal attitudes regarding water in New Mexico. The position of these small operators on the fringe of the great centers of technical application played a major role in the formulation of water policy. The collective force of these feelings of the small water user often came into conflict with the grandiose plans of government agencies.

The picture was quite clear: more and more technology was applied to the already massive irrigation projects in the Rio Grande and Pecos Valleys, and in the other major water-sheds of New Mexico, but across the back country the process was different. While plastic pipe was making a deep imprint on the rancher, large and small, as electricity gradually replaced wind as the primary source of power to raise water from the subsurface, and massive machinery and cement replaced the simple gouged-out dirt irrigation ditches, still much remained in New Mexico of the ancient ways. In the small villages, so much a part of New Mexico's scene, the symbol of technology is the lowly shovel. Without the shovel the primitive ditch system will fail. Acquiring water for livestock in the back country is not always much better, and in many areas only the most rudimentary technology developed.

Also evident was the fact of overdeveloped technology, particularly in the areas with reliable surface water flow and agricultural potential. Large doses of technology by the private and public sectors have frequently allowed over appropriation of available water, both surface and subsurface. There is even more, for the problems in these areas are now requiring an even heavier application of technology in their solution. A similar situation is developing in the livestock industry. The use of plastic pipe, better well-drilling capacity, and electric pumping power has allowed rapid expansion and dispersion of water resources. The cost, however, has been high, not only in terms of money and capital, but also in terms of expanded use of forage. In many areas more water has resulted in more livestock on lands already overgrazed, a critical factor in the deteriorating ecological patterns in New Mexico. This is, of course, an overstatement, for good range management can compensate for the pressure brought for more income to recoup capital invested in water resource development. It is true, however, that increased water availability brings with it a demand for greater animal carrying capacity.

The history that unfolded, then, was one of well advanced technological applications backed by sound scientific principles, blended with a primitive simplicity mixed with superstitions, old wives' tales, magic, and faith. The results for New Mexico are troublesome as the State tries to formulate public policy out of these diverse sets of values. It is even more difficult for federal government officials, for they are even further removed from the local beliefs and frequently do not understand the apparent backwardness or the unscientific ideas. When discussing water resource development in New Mexico, one must speak of the highly sophisticated science of hydrology on the one hand, and of water witching on the other. Both are in use in New Mexico in 1973, and the latter may be more prevalent. They are prime examples of the two faces of New Mexico's evolving water technology.

The answer to the question of "why" the backwardness, often the open rejection of science and technology, had two explanations. The first was economic. The small water user was generally poor in capital. This explanation has been grossly overstated. Equally or more important in this apparent rejection were the social and cultural factors, factors having their origins in the historic past. They came from the conservative, suspicious, and age-old traditional societies of Indian and Spanish New Mexico.

As the people of New Mexico move toward further development of their water resources, and as new scientific principles are brought to light and new technical levels are achieved, it might be hoped that all areas and all societies are included. The massive amounts of money expended on water resource development and water control for special areas has had no comparable expenditure on the village systems.

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