WATER AS A LIMITING FACTOR IN INDIAN ECONOMIC DEVELOPMENT

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ABSTRACT

A preliminary study was undertaken to determine the effects of water supply on the cultural and economic development of the Pueblo Indians of New Mexico, both past and present. A survey of the historical and anthropological literature concerning the development of Pueblo cultures was conducted with special emphasis on the influence of water supply and other environmental factors. In addition, a general description of the Pueblos' current economic conditions was derived from several recent studies.

The availability and quantity of water in an area had an important impact on the development of Pueblo culture and the particular agricultural techniques used. Agriculture was originally possible only in areas suited for dry-farming. As agriculture assumed a more important role in the economic pattern of the Pueblos techniques were developed to make more efficient use of the rainfall, to utilize other sources of water, and to adjust to slight environmental shifts. Availability of sufficient agricultural water was an important factor in the process of establishment and abandonment of settlements, a process which ended in the eventual settlement of the majority of Pueblos in New Mexico.

The arrival of the Spanish, Navajo and Apache raiders and later the Anglo-Americans resulted in changes in the Pueblos' environment that affected their options for adjustment. Their careful balance between culture and environment has broken down. They must deal not only with changes and fluctuations in the physical environment, but also with outside social and political forces. Future Pueblo economic development will depend on their ability to deal with these forces in securing water and other economic resources.

Introduction

It was the initial observation of the project's investigators that the Indians of the Southwest United States, particularly the Pueblo Indians of New Mexico, have been relatively more isolated from contacts with the dominant culture than Eastern and Northern Indian groups, and, therefore, have been able to retain a strong cultural identity. It was observed further that one of the factors in this isolation could be that many of the largest urban population centers in the U.S. are located near large bodies of water (e.g., the Atlantic and Pacific Oceans and the Great Lakes), or in areas that have an abundant supply of water in general (e.g., heavy annual rainfall, rivers, lakes, etc.). The Indian groups living near these urban centers have experienced a much higher degree of acculturation to the dominant society than Southwestern Indians. Since the Southwest lacks large bodies of water, a comparable water supply, and large urban areas, it was suggested that the degree of water availability in the Southwest may have been an important factor in the prehistoric development of Pueblo cultures and in the preservation and maintenance of these cultures at the present time. The purpose of this study, therefore, is an attempt to determine the impact of environmental factors in general and water supply in particular on the development of Pueblo cultures in New Mexico before and after contact with European cultures. Special emphasis is given to the effects of water supply and other environmental conditions on the economic aspects of these cultures.

In view of these premises the following questions concerning the Southwestern environment and the history of Pueblo cultural and economic development were formulated and pursued:

1. What are the main characteristics of the Southwestern environment? How did these characteristics influence the emergence and general development of Pueblo cultures in the area?
2. What was the effect of water supply as a specific environmental factor on the development of the subsistence of economic aspect of Pueblo cultures?
3. What role did water supply have in the location of Pueblo settlements?
4. What was the effect of environmental changes and, particularly, changes in the water supply on Pueblo culture and economy?
5. Can differences between Pueblo cultures in terms of social organization and level of subsistence be related to differences in water availability or water-use technology?
6. What was the impact of contact with Spanish culture on the Pueblos? What was the impact of Spanish settlement on the interrelationship of Pueblo culture and environment? What was the effect of subsequent Anglo-American settlement?
7. What is the present-day relationship between Pueblo culture and environment in general, and, more specifically, the relationship of Pueblo economies and water availability?

Definitive answers to these questions have not been sought, but rather an attempt has been made to determine whether or not study of water availability, past as well as present, is a promising avenue for further research concerning Pueblo Indian economic development. As a result only general

information relating to these questions has been gathered, primarily through a review of the pertinent anthropological and historical literature concerning the development of Pueblo culture and economy, and information gathered from recent studies dealing with Indian economic problems.

Before beginning the discussion of the research questions the New Mexico Pueblos should be identified. There are nineteen Pueblo groups in New Mexico which can be classified for the purposes of this study on the basis of two criteria.

Linguistically the Pueblos can be divided as follows:

Kiowa-Tanoan

a) Tiwa (Taos, Picuris, Sandia, Isleta)

b) Towa (Jemez)

c) Tewa (San Juan, Santa Clara, San Ildefonso, Nambe, Pojoaque, Tesuque)

Keresan

a) Eastern Keresan (San Felipe, Santa Ana, Zia, Santo Domingo, Cochiti)

b) Western Keresan (Acoma, Laguna)

Zuni

These linguistic divisions correspond closely to differences in culture and social structure (Dozier, 1970).

The Pueblos can also be divided according to the source of their present water supply. The Tanoan and Eastern Keresan Pueblos are all situated in the Rio Grande Valley, either on the river itself or its tributaries, which gives these pueblos, potentially at least, an ample permanent supply of water. These are referred to as the Eastern or Rio Grande Pueblos. Zuni and the Western Keresan Pueblos (Western Pueblos) are located on the plains and plateaus west of the Rio Grande Valley and do not have a

permanent water supply comparable to the Rio Grande Pueblos. These pueblos depend on rainfall and small, intermittent streams and springs for their water supply (Dozier, 1970).

There is one other major Pueblo group, the Hopi of Arizona. Although this study was originally intended to deal with only the New Mexico Pueblos, in tracing the development of Pueblo culture it is necessary to explore developments outside New Mexico. As will be seen, the Pueblo culture developed over a wide area of the Southwest before its final concentration primarily in New Mexico. The Hopi represent one of the patterns that contributed to the Pueblo configurations in New Mexico and, therefore, several references to them are made. The Hopi have their own language distinct from any of the other Pueblos, and with respect to water supply, they would be included with the Western Pueblos.

The Southwestern Environment

The physical environment of the American Southwest (a term which here refers to the present-day states of Arizona and New Mexico and to southern Utah and Colorado) is one of the most diverse and spectacular in the world with wide variations in factors such as temperature, altitude, land forms, precipitation, vegetation, and animal life. It has been stated that altitude and water are the principal factors in the southwestern landscape (Amsden, 1949). Water varies directly with altitude, that is, the higher the altitude the higher the annual rate of precipitation which, in turn, influences the quantity and flow of the streams and rivers in an area. As altitude and precipitation vary so do other elements of the environment including the forms and patterns of life, human and non-human.

There are three distinct environmental settings in the Southwest corresponding to three combinations of precipitation and altitude: desert, plateau country, and mountains. In each one of these areas a distinctive Indian culture developed which contributed to New Mexico Pueblo culture (Haury, 1956).

The desert region of the Southwest is characterized by altitudes ranging from approximately sea level to 2,500 feet; annual precipitation rates of 5-8 inches or less; and the highest average year-round temperatures of the three types. The landscape is flat, dry and barren, intersected occasionally by a major river, and dry stream beds and arroyos. The meager vegetation consists of scrub grasses, mesquite, and various types of cactus. The animal life is equally restricted being limited to rodents, reptiles, birds, and coyotes. The main desert region is located in southern Arizona and is drained by the Salt and Gila Rivers which originate in the mountains of east central Arizona and western New Mexico.

The plateau country is distinguished by elevations of 2500-6000 feet; precipitation rates of 8-15 inches per year; and temperature ranges that are less extreme than either the desert or mountain regions. The landscape rises from broad plains to high extensive tablelands which are intersected by steep canyons and broad valleys cut by streams and rivers. The natural vegetation consists of grass cover, bushes and small trees such as scrub oak and pinyon. Small game animals are common. The plateau country is probably the most extensive type in the Southwest, covering great portions of northeastern Arizona, northwestern and central New Mexico, southwestern Colorado, and southeastern Utah. The major river systems of this region are the Rio Grande, San Juan, Colorado, and Little Colorado.

The mountain areas, which surround and sometimes cut across the plateau and desert country, are characterized by elevations of from 6000-13,000. Precipitation varies from 15-20 inches per year in the lower reaches to 40 inches and more (including snowfall) in the highest elevations. The runoff from this heavy precipitation forms countless small streams and provides the source of the major rivers of the Southwest. The mountain areas have the lowest temperatures with pleasantly mild summers and extremely cold winters. The mountain landscape is quite spectacular with dense forests of pine and other trees in the lower and middle reaches and bare, jagged, rocky peaks, some of which are snow capped year-round. The lower and middle ranges of the mountains are also the home of a great variety of animals and birds, everything from squirrels and sparrows to deer, bear, and eagles.

The southwestern environment, for all its variation, has been basically stable for the past 10,000 years (Smiley, 1961), that is, for most of the time that the area has been inhabitated by humans, and during the time that the features of Pueblo culture were being developed. The only changes have been relatively small fluctuations in average temperatures and precipitation rates, and changes in the pattern of precipitation distribution throughout the year. Although it can be said that these changes are minor in an absolute sense (a difference of a few inches of rain or a few degrees of temperature) in a relative sense they can have a major impact on the subsistence patterns of primitive groups living in this arid to semi-arid region (Moore, 1960).

Early Southwestern Inhabitants

This section is intended to be a brief description of early human occupation of the Southwest. The main emphasis will be on the relationship of the subsistence patterns developed by the early inhabitants to water supply and other features of the southwestern environment.

The earliest evidence of man's existence in the Southwest is also some of the earliest evidence of man in the New World. The predominant theory is that during the period 15,000-10,000 B.C. migrating bands of Asiatic peoples crossed the ice-bound Bering Strait and continued southward through a gap in the two main glacier formations on the North American continent (Jennings, 1968). These people had apparently been part of a big-game hunting culture which was continued and amplified in the New World. There are several well-studied sites (Sandia Man and Folsom Man) that confirm the existence of hunting groups along the Rio Grande and the eastern plains of New Mexico possibly as early as 12,000 B.C. (Jennings, 1968). These people traveled in small bands following the herds of mastodon, giant bison, and other large game animals that they depended on for their subsistence. Eventually, through a combination of over-hunting and climatic changes (a general shift to dryer conditions Smiley, 1961) the big game animals became extinct (Woodbury, 1963). There was a shift to the other major subsistence pattern of primitive, non-agricultural peoples, the hunting of small game and gathering of wild plant foods (Woodbury, 1961a). The southwestern expression of this subsistence pattern with its associated artifacts, referred to generally as the Desert Culture (Jennings, 1968), extended beyond the Southwest proper. Sites have been found throughout the Great Basin region of North America from Oregon to northern Mexico.

The significance of the Desert Culture pattern to the discussion of the development of Pueblo culture (with its distinctive features of sedentary village life, permanent masonry dwellings, and an agricultural subsistence economy, Reed, 1946) is that since it preceded Pueblo culture in the Southwest some of its achievements and characteristics became the basic and fundamental elements on which Pueblo culture was built. These hunter-gatherers occupied some of the same areas as the later Pueblos and faced the same physical environment. Although the specific styles of developments in material culture and technology varied throughout the Desert Culture area, the basic inventory of material goods was essentially the same. Suitable implements were developed for hunting, preparing, and cooking small game; and for gathering, processing, storing, and cooking wild plant foods, especially seed foods. These developments made it easier to incorporate cultivated plant foods into the subsistence pattern when they were introduced (Woodbury, 1963).

Another basic characteristic of the Desert Culture pattern which has importance for the development of Pueblo culture is the tradition of close adaptation to the environment of an area and thorough exploitation of its resources, no matter how scarce or limited (Jennings, 1968; Woodbury, 1963). This includes, among other resources, the water supply. Since these people were not farmers and were not sedentary, their water needs were small (enough water for drinking, cooking, and washing) and they most likely made their temporary camps within easy access to streams, springs, or other sources of water. But water supply in the form of rainfall could have an important, although indirect, effect upon their subsistence pattern.

Although it has been noted that the environment has remained relatively stable in the Southwest there have been recurring cycles of erosion and sedimentation which have altered the land surface at different times (Smiley, 1961; Bryan, 1941). These cycles are related to changes in the pattern of precipitation distribution and intensity throughout the year. The typical sequence in the Southwest is that a change in the rainfall pattern takes place from a situation in which the rainfall is fairly evenly distributed during the year and/or the rainfall intensity is normal, to one in which the major portion of the annual rainfall comes in the form of sudden, violent, intense thunder storms in the summer. When the shift is to a summer dominant pattern the ground is generally very dry when the rains come. The rain falls so quickly and intensely that it is not able to soak into the ground, but runs off at a faster than normal rate carrying much topsoil with it. The ground cover vegetation does not have enough moisture or topsoil to sustain it and graudally dies off leaving the land more vulnerable to the intense rain. At the same time (if the pattern continues) the stream beds, which receive the runoff, are deepened and enlarged by the rapid flow and greater volume of the runoff. This entire process leaves the land deeply eroded and barren (Bryan, 1941).

If and when the rainfall pattern shifts again to one of more evenly distributed, less intense rain, the sedimentation phase of the cycle begins. The less intense rain soaks into the ground, the runoff is slower, much of the sediment in the runoff is deposited in the arroyos gradually building them up, the vegetation has a chance to reestablish itself, and the land slowly heals. Bryan has shown that this cycle has been repeated throughout the Southwest at different times and places, and is still occurring,

however, there are now effective methods to minimize the damage of the erosion cycle.

It is easy to understand how this type of cycle could have serious effects on primitive agriculturalists, but it can also be shown that the effects upon hunting-gathering groups are equally serious. During the erosion cycle the forms of animal life dependent on plant food would either die or migrate; the same thing would happen to predatory animals; and the human inhabitants of the region, deprived of both plant and animal foods, would suffer the same fate (Woodbury, 1961a).

One might suggest that since these people were non-sedentary in the first place, the erosion cycle and the need caused by it to migrate to another area would not present such a hardship. However, the evidence indicates that although these people had no permanent villages and were mobile in their pursuit of food, the movement of individual bands took on a stable pattern and the radius of their seasonal wanderings was relatively small. There is also evidence which shows that they collected surplus food; stored it, together with many implements and artifacts, at some of their campsites; and returned to these sites at various times during the year (Jennings, 1968). In addition, the Southwest is a region in which subsistence for hunting-gathering groups was always difficult. Knowledge of an area, its resources, and the techniques to make the most of these resources was the key to survival. When an environmental change diminished either the inventory or the supply of resources in an area, attempts to adapt to the new conditions were the first steps taken. With both the investment in knowledge and material goods to consider, migration becomes an alternative only when the area will no longer support the population. Even under these circumstances the

process of abandonment of the area is likely to be gradual. Thus, it can be seen that the necessity to migrate caused by an environmental change was a significant and disruptive occurrence for Desert Culture peoples. As will be seen in subsequent sections of this report, this pattern of thorough adaptation and exploitation of an area even in the face of environmental change, is an important characteristic of Pueblo culture (Jennings, 1968).

Agriculture, Water Supply and Three Southwestern Cultures

The first major change in the Desert Culture pattern which contributed to the development of New Mexico Pueblo culture was the introduction from Mexico of agriculture, and, of less importance for this discussion, the knowledge of pottery making (Dozier, 1970). The gradual appearance of these traits in various parts of the Southwest and the differing adaptations to them resulted in three main cultural configurations which contributed to Pueblo culture. These three cultures are the Mogollon, Hohokam, and Anasazi. Before going on to describe these three cultures a few comments on the significance of agriculture in the Southwest are in order.

It has long been held that the development of agriculture is the foundation for the development of higher civilizations. Agriculture provides food surpluses with less time and labor than hunting and gathering. These surpluses, in turn, allow for population growth, the development of urban centers, and the subsequent development of arts, crafts, technology, and knowledge in many other areas (Adams, 1971). This is fundamentally true for the Pueblo cultures of the Southwest in spite of the fact that they did not approach the level of the most highly developed cultures of North America, the Aztecs and Mayas. It was basically their steadily increasing dependence on the cultivation of maize that gave them the freedom to develop the distinctive material, social, and religious aspects of their culture (Woodbury, 1963).

The existence of agricultural societies in arid or semi-arid regions has been noted in wonder (Bryan, 1941). It is easy to see how the possibility of having a stable food supply would have special appeal to people living in a region where the procurement of food is a difficult all consuming task; but how is such a development possible for primitive hunting-gathering peoples living in areas with so little rainfall? In a region as large and diverse as the Southwest there are areas where the factors necessary for maize cultivation, arable land, 120 day growing season, and water, are found. It is in these areas that agriculture was first practiced (Carter, 1945). Of these three factors only the water supply was capable of being manipulated or affected by the early Indian farmers (Woodbury, 1963). Therefore, the growth and expansion of agriculture in the Southwest was dependent on the Indian farmers' ability to devise techniques to make efficient use of the water supplies available to them. This section, then, will be an examination of the development of the three main Southwestern cultures emphasizing their increasing dependence through time on agriculture and the adjustments made and techniques developed to control and affect the water supplies at their disposal.

The Mogollon is the earliest of the three and the dates of its existence as a distinguishable, viable culture are usually given as 300 B.C. - 1350 A.D. (Jennings, 1968). The main area of Mogollon influence is southwestern New Mexico and southeastern Arizona, and most sites are found in areas characterized by steep mountains and narrow valleys (Haury, 1956). There is less arable land available than in the areas covered by the other cultures but because of the elevation there is more rainfall and agriculture

is possible. Evidence of cultivated plant foods is found in the Mogollon area as early as 2,000 B.C. (Jennings, 1968) when the area was still dominated by the Desert Culture pattern. Therefore, it is apparent that some Desert Culture peoples knew about and utilized domesticated plants but only as a minor supplement to the still dominant hunting-gathering pattern. The most likely pattern of the earliest agriculture practiced by Southwestern groups is that a primitive strain of maize was planted in small plots near stream beds, rivers, arroyos, and any other place where there might be sufficient moisture from rainfall and flooding to produce a crop (Jennnngs, 1968; Schoenwetter and Dittert, 1968). These small plots were generally attended by a few people while the majority of the band continued its round of hunting and gathering activities, returning in the fall to help with the harvest (Woodbury, 1963).

With the appearance of pottery, the beginnings of pit-house style dwellings, the introduction of beans and squash, and a greater dependence on improved varieties of maize the Mogollon culture distinguished itself and emerged from the surrounding Desert Culture around 300 B.C. Anthropologists distinguish several developmental phases within the history of the Mogollon culture. Each phase is marked by improvements in material culture, technology, and changes in the area covered or influenced by the culture. During the last phase (1100-1350) the Mogollon people came more and more under the influence of the Anasazi culture to the north. They abandoned their typical pit-houses and adopted the above ground multistoried masonry style of the Anasazi. Gradually the core area of the Mogollon culture was abandoned and by the time the Spanish entered the Southwest there were no representatives of this culture pattern that had not been greatly changed

by Anasazi influence. It is believed by some scholars that Zuni contains more remnants of Mogollon culture than any other New Mexico pueblo and this may have some bearing on the many differences observed between Zuni and both the Rio Grande and the Western Keresan Pueblos (Jennings, 1968).

In terms of agricultural and water use technology the Mogollon used fewer of the known techniques than the other two cultures (Woodbury, 1961b). This was because the mountainous environment of the Mogollon was more abundant in wild game and plant foods than other Southwestern areas where agriculture was practiced, and as a result the hunting and gathering pattern retained a higher degree of importance. Because of their general mountain environment availability of sufficient water for agriculture was less of a problem than finding sites for garden plots which were level enough to hold moisture from rainfall and stream runoff (Jennings, 1968). Their water utilization techniques usually involved methods for creating level plots of arable land and for slowing down the flow of runoff so that more moisture would be retained by the plants. Low stone walls called "terraces" or "check dams" (Woodbury, 1961b; Steward and Donnelly, 1944) were built across intermittent streams to hold small plots of soil and to slow the occasional stream flow to allow it to penetrate the soil. For hillside fields parallel rows of stones were laid across the fields in lines or grid formations to slow the runoff and to prevent the soil from washing away. Like other Southwestern farmers they depended on their knowledge of the area as much as on their technology to produce crops. Fields were planted in different locations with differing conditions and techniques in the hopes that a crop would be produced from some, if not all, the fields (Woodbury, 1961b).

The Hohokam. The second major culture pattern in the Southwest which had an effect on the Pueblo cultures of New Mexico is the Hohokam culture of south central Arizona in the Salt and Gila River basins. This is a basically arid region with average annual rainfall of usually less than 10 inches, however there are some sites within the region which permitted dry farming (Carter, 1945). This culture also emerged from a Desert Culture pattern and its dates are usually given as 100 B.C.-1400 A.D. (Jennings, 1968). This culture shares many similarities with the advanced Mexican cultures to the south and there has been some speculation that some of the more sophisticated elements of Hohokam culture (ceremonial ball courts, small pyramids, ornamental artwork, and irrigation) may have been introduced directly by migrants from Mexico who joined the Hohokam (McGregor, 1965). In any case, the Hohokam were influenced more directly by Mexico than the other two Southwestern cultures.

In some areas of the Hohokam region agriculture was possible by floodwater farming practices. Fields were planted on the flood plains of arroyos and stream beds and watered by the floods and runoff from local rainfall and rainfall from the nearby mountains (Bryan, 1941; Stewart, 1940). Over a long period the Hohokam developed extensive and sophisticated irrigation systems. They first built canals and ditches to carry floodwaters to their fields and later tapped the waters of the Gila and Salt Rivers directly. Around 500 A.D. small-scale irrigation systems were begun by single villages and by 1100 the systems had become much larger, with major canals as much as 60 feet wide and 10 feet deep and able to water fields 15 miles from the river (Haury, 1956; Woodbury, 1961c). These larger systems were the result of inter-village and town cooperation which indicates a higher level of

political and social integration than that achieved by other Southwestern cultures (Haury, 1956). Although the area has a growing season of over 200 days and Hohokam farmers could make use of the rainfall whatever time of year it was most abundant, irrigation from the rivers was the most reliable method to produce a crop in this arid region and the only one that would permit the growth of population, large towns and the other developments that are characteristic of the highest achievement of Hohokam culture.

During the last phase of Hohokam culture these people also came into closer contact with the Anasazi and no doubt exercised mutual influences over each other. There is evidence of Anasazi settlements existing side by side with Hohokam villages in areas of central Arizona that had been largely dominated by the Hohokam (McGregor, 1965). For reasons not yet fully understood the major sites of Hohokam culture were abandoned by 1400. One theory is that the Hohokam were being pressured by recent arrivals of new nomadic groups in the area and perhaps by hostile, more aggressive groups among the Hohokam. The conjecture is that the more advanced Hohokam probably migrated and took residence in Anasazi settlements (McGregor, 1965). When the Spanish arrived the area of greatest Hohokam development was occupied by the ancestors of the modern Pima and Papago tribes who possessed a level of culture similar to the earlier stages of Hohokam culture.

The Anasazi. The culture pattern that had the largest influence on the New Mexico Pueblos was the Anasazi. Although this culture was the last of the three to emerge from the Desert Culture pattern (around 100 A.D.), and received its initial stimulus from the Mogollon, it eventually incorporated both Mogollon and Hohokam and became the dominant pattern in the Southwest. The main area of Anasazi development and elaboration was the high plateau

country of southwestern Colorado, northwestern New Mexico, southeastern Utah, and northeastern Arizona (Haury, 1956).

The development of Anasazi culture has been classified into two main phases, Basket-Maker and Pueblo, and each of these then divided into several stages identified by particular developments in material culture (Jennings, 1968). The initial Basket-Maker phase is essentially the same as the Desert Culture for this region, but with the second Basket-Maker stage there is a differentiation from the Desert Culture pattern with the limited practice of agriculture. The subsequent Basket-Maker stages (the number of stages depends on which classification is being used, but all agree generally on the duration of Basket-Maker culture and the period of its transition to the Pueblo phase) are distinguished by the introduction of pottery and improvements in its techniques; increased dependence on agriculture; and the pit-house style of architecture. The transition from the Basket-Maker to Pueblo phase occurs about 750 A.D. and is marked by the beginning of surface masonry architecture (Jennings, 1968).

The various stages of Pueblo culture are marked by new styles and techniques in pottery-making, craft specialization, and improvements in their architecture which culminated in the large multi-storied pueblos that housed hundreds of people in core Anasazi areas. In addition to the material changes that are most often mentioned by archaeologists are improvements in agriculture and water-use technology and the concurrent development of patterns of social organization which taken in total made large-scale population concentration possible. Examples of this "classic" stage of Anasazi development which occurs between 1100-1300 are the great cliff dwellings at Mesa Verde, and the pueblos of Chaco Canyon and Canyon de Chelly. The

Anasazi are generally thought of as a sedentary people who built and occupied great pueblo cities, however, as Jennings and others point out, these are the highest achievements of Anasazi culture and are not to be considered typical of the whole area of Anasazi influence. As agriculture became the most important element in the Anasazi susbistence pattern they often had recourse to their earlier Desert Culture and Basket-Maker traits of mobility and areal exploitation to find new combinations of land and water to carry out their agricultural economy. Jennings notes that in addition to the relatively few large pueblo sites in the Anasazi area there are countless sites with just a few houses where small groups, probably family or lineage groups, had branched off from the larger settlements to exploit previously unused resources. Naturally, these small settlements would not be expected to exhibit the same degree of development that is found in the large pueblos in terms of material culture and agricultural technology.

The Anasazi practiced dry farming where possible and used a variety of floodwater techniques adapted to specific local conditions. In its earliest stages Anasazi agriculture was performed much like the Mogollon by very simple methods requiring little or no technological innovation or human attention (Schoenwetter and Dittert, 1968). It is believed that during the Basket-Maker stage and the early Pueblo phases (100-1000 A.D.) the annual precipitation in the plateau region was slightly higher and the rainfall pattern was one of fairly even distribution with perhaps a slight winter-dominant pattern (Smiley, 1961). This pattern made dry farming possible in many regions of the Southwest where it would now be unfeasible. The heavier winter precipitation provided ample ground moisture for the germination and early growing stages of maize and, in general, the spring and summer rainfall

was adequate and distributed evenly enough to mature the crop. Agricultural expertise at this time consisted primarily of the farmer's knowledge of the local terrain in terms of which areas generally received the most rainfall and runoff, had good soil, and a growing season of sufficient length for maize.

There is evidence that between 900 and 1000 a climatic change began to occur in the Southwest to a summer dominant precipitation pattern (Hill, 1970; Vivian, 1970) in which the summer rains came in the form of heavy brief thunderstorms. This change coupled with a trend toward drier conditions (lower precipitation and/or warmer temperatures) signaled the beginning of a new erosion cycle which had serious implications for Anasazi agriculture (Woodbury, 1961a). Dry farming was no longer possible in many areas either because of insufficient winter and spring precipitation for the early stages of maize growth, or because the summer rainstorms were more damaging than helpful, washing away the soil and uprooting the plants. Floodwater farming was also jeopardized by the summer thunderstorms. Fields on the flood plains of streams and arroyos could be uprooted by the heavy runoff or buried by the great quantities of silt and sediment that it carried. The use of water control structures and methods is dated from this time and it is believed that they were developed in response to the climatic shift (Vivian, 1970).

By this time the Anasazi were committed to a sedentary agricultural existence. Large multi-storied pueblo towns with populations in the hundreds were already thriving in Mesa Verde, Chaco Canyon, and other Anasazi core areas. After the change in the rainfall pattern some areas were no longer capable of sustaining an agricultural existence because the winter precipitation

received was insufficient for early maize growth, even with strategic selection of fields and deep planting. Settlements in this type of area were abandoned. In those areas which still received sufficient winter precipitation or had ground moisture from other sources techniques were developed to capture the large amounts of water available in runoff after a heavy thunderstorm, slow down the flow of the runoff and divert as much of it as possible onto the fields and garden plots. Some of these techniques served an additional purpose of soil conservation (Stewart and Donnelly, 1944; Vivian, 1970; Woodbury, 1961a). Although the principles and purposes of these agricultural methods were essentially the same throughout the Anasazi area the techniques used at a particular site were adapted to fit the local conditions. The succeeding paragraphs will describe the general techniques and some of the specific adaptations made at particular sites.

The Anasazi had practiced two basic types of floodwater farming and with a few adjustments and simple innovations these methods retained their importance in the Anasazi agricultural economy. For fields planted on the flood plains of water courses that carried runoff in the spring or after a rain steps were taken to slow the force of the runoff flow and to minimize its destructive effects. Sometimes series of large stones were placed in the waterways to help slow the runoff. Small structures of brush, stone, and earth were put up along the water course to slow the water and divert portions of it onto fields along the waterway. Once the floodwaters reached the fields small structures placed at strategic points on the field intercepted the water, slowed its flow even more, and helped spread it out more evenly over the field. In addition, earthen ridges about 12"-18" high were sometimes formed around a field or a portion of it to hold the water on the

field longer to allow the water to soak deeply into the soil (Stewart, 1940; Stewart and Donnelly, 1944; Vivian, 1970; Woodbury, 1961b).

The other basic type of floodwater farming is to select a field that lies in a position to receive sheet runoff from a much greater area (Bryan, 1929). By placing rows of stones on the field in line or grid formations to slow the runoff and prevent the soil from being washed away this method was still applicable. The method was noted for the Mogollon also and is useful for sloping hillside fields as well as relatively level fields (Stewart and Donnelly, 1944; Woodbury, 1961b).

In addition to adapting old methods to the changed climatic situation the Anasazi developed new techniques to utilize the runoff. One method was developed which involved slowing the runoff and building small garden plots as well by constructing low dams of stone and sometimes mortar across sloping stream beds and gullies in their upper reaches. Over a period of time sediment from the intermittent stream flow and runoff accumulated behind the dams providing small garden plots which ranged in size from 6'x 9' to 20'x 50' (Stewart and Donnelly, 1944). These small garden plots were very dependable in producing crops because nature had concentrated an abundant supply of water in these stream beds in the form of runoff and the construction of these dams slowed the runoff enough to make it highly effective. These "terraces" as Woodbury calls them are most commonly found in the streams that run down the sides of mesas, in canyon bottoms, and in other intermittent waterways with sufficient grade and flow for soil accumulation. Evidence for this type of structure has been found at Mesa Verde, Point of Pines in Arizona, and other sites scattered throughout the Southwest (Stewart and Donelly, 1944, Vivian, 1970, Woodbury, 1961b).

While the construction of these "terraces" no doubt required much work on the part of Anasazi farmers they were essentially small simple structures that could be built and maintained by single individuals or small family groups (Woodbury, 1961b). Other methods for controlling the great amounts of water available as runoff were devised which required the cooperation of larger groups of people to build and maintain. These methods, associated primarily with the large pueblo towns in the Mesa Verde and Chaco Canyon areas, involve the construction of ditches, dams, reservoirs, and large diverting structures to capture, save, and direct the large volume of runoff onto the fields.

At Mesa Verde there is evidence on the upper end of Chapin Mesa of a large reservoir called Mummy Lake in which runoff was collected. There is also a system of ditches and small diversion structures to irrigate fields at the lower end of the mesa with water from the reservoir and runoff at the time of a rain. The layout of these ditches indicates that they served fields belonging to several pueblo towns which in turn indicates a measure of inter- as well as intra-village cooperation in the construction and maintenance of this system. The ditches themselves, which were relatively wide, flat, and shallow, were sometimes planted with corn. Rows of stones were placed in the bed of the ditch to slow the force of the runoff for the benefit of the corn plants as well as to prevent the erosion of the ditch (Stewart, 1940; Stewart and Donnelly, 1944).

In 1000 A.D. Chaco Canyon was an area that had been occupied continuously by Anasazi groups for over 500 years and was one of the centers of Anasazi cultural development (Vivian and Mathews, 1964). It was the site of countless pithouse villages and after 750 A.D. the site for pueblo villages

and large towns, many on the canyon floor itself and some on the surrounding mesa tops. Farming had long been the economic mainstay of the people, being carried out on the canyon bottom by dry farming and simple floodwater methods; however, the climatic shift to a summer dominant pattern made dry farming unreliable. In response to this climatic shift some of the most elaborate and efficient systems for control of runoff in the entire Anasazi area were built and operated by the larger Chaco towns (Vivian, 1970).

The main purpose of these systems was to control, collect and direct the great amounts of runoff on the mesa tops for use in the canyon bottom fields. Towards this effort several different types of structures and systems were devised and constructed. One method consisted of building large stone and mortar dams across tributary canyons to trap the runoff that naturally flowed into them. The dams were built with gate structures in the centers to release the flood waters into specially built channels that carried the water to the fields on the main canyon floor. The remains of one such dam measured 120 feet long, 20 feet wide, and 7 feet high (Vivian, 1970). The canals themselves were either above ground structures of stone and mortar or excavated ditches lined with slabs and mortar for longer wear. The canals varied in size depending on whether they were main channels from the dams and reservoirs or feeder ditches to the individual fields and plots. They ranged in size from 9 to 50 feet wide, 2 to 5 feet deep and from 200 feet to 3 miles in length (Vivian, 1970).

Another method involved the use of stone and mortar "collecting walls" situated on the mesa top in such a manner as to intercept the natural flow of the runoff, collect it, and direct it to a "pour off" point on the cliff edge where it would spill over either into a natural drainage or specially

constructed canals and reservoirs for use on the canyon floor. These "collecting walls" were impressive structures some being over 1500 feet in length while most were usually 2 feet high and wide. There were also ramp-like structures of slab and mortar construction at the "pour off" points to control the flow and prevent erosion of the cliff edge and the over accumulation of silt and sediment in the water. The canals associated with these systems were much the same as those associated with the canyon dam systems in size and design. The reservoirs near the village and town sites filled from these canals served domestic as well as irrigation purposes (Vivian, 1970).

Evidence has been found at Chaco Canyon for a variation on the terrace-like garden plots noted for other Anasazi sites. Long low stone walls similar to the collecting walls but averaging about 100 feet in length are found on the sloping mesa sides below a point where the runoff naturally spills over and soil can be accumulated to form a garden plot about 90 x 25 feet in size. Vivian calls these structures and the garden plots associated with them "farming terraces". Stones are placed along the runoff points to stabilize the cliff edge and to slow the force of the runoff as it spills over into the garden plots. The main differences between these "farming terraces" and the other terraces described here are in size and in the fact that the Chaco Canyon terraces are located on the mesa sides rather than known stream beds or gullies.

There is some evidence that points to the use of irrigation from live or permanent water supplies by the Anasazi (Lindsay, 1961; Sharrock, et.al., 1961, Stewart and Donnelly, 1944). However, it is limited to the irrigation of small village garden plots from adjacent springs or small-scale ditch

irrigation from flowing streams, and is found at very few sites where agricultural practices have been taken into consideration. Nowhere in the Anasazi area prior to the general abandonment of the area (a topic to be discussed in more detail later) is there evidence of irrigation structures and systems comparable to the Hohokam. The sites where evidence of irrigation from streams was discovered were relatively short-lived settlements on the fringes of the main Anasazi area, and were occupied mainly between 1100-1200 (Lindsay, 1961). It seems likely that these settlements were founded in response to population pressures and agricultural difficulties due to climatic fluctuations in the areas of Anasazi concentration. It appears that the inhabitants of these settlements, in response to changing conditions, were experimenting with various agricultural techniques including stream irrigation.

Joyce Herold (1961) has suggested that irrigation from the San Juan, La Plata, Animas, and other rivers in the northern New Mexico, southern Colorado area would have been necessary to support the large pueblos in these river valleys that were built and occupied during the "classic" period. She bases her argument for the "necessity" of irrigation from modern evidence of precipitation rates in these valleys which she concludes are too low to support dry or floodwater farming on the scale needed to support the large population of these areas. She hypothesizes that these pueblos grew up in the valleys because of the same population pressures and climatic changes noted before, and also, more importantly, because of the development and knowledge of irrigation technology. This last factor is subject to some dispute.

It has been stated here that experiments with stream irrigation were rare among the Anasazi and that they had developed effective techniques of floodwater irrigation using natural water channels supplemented at some sites by man-made ditch systems. It could be argued that the Anasazi probably were familiar with and may have learned the use of stream and river irrigation from the Hohokam since it has been pointed out that the two groups occupied some of the same areas in central and northeast Arizona in the "classic" Anasazi period. However, there is not enough evidence to indicate that the Anasazi had sufficient experience and expertise with river irrigation technology prior to extensive settlement in the river valleys to expect to find the kind of large-scale irrigation systems Herold postulates. In fact, Herold admits that there is no firm archaeological evidence that such systems did exist, but she puts this down to inadequate study of these sites and to the notion that the archaeologists working in this area may not have been interested in nor paid attention in their excavations to indications of possible agricultural practices. However, twelve years after publication, these reasons can no longer be used. Although no area is ever studied as thoroughly as would be desirable, over the years the general Mesa Verde area has been as extensively surveyed as any. Further, it is hard to believe that any archaeologist, no matter what his interests, could fail to observe and mention indications of relatively large-scale irrigation systems, if they do in fact exist.

It appears, then, that the Anasazi's reaction to climate change was to improve their floodwater techniques and resettle when necessary where these techniques could be used. Although sophisticated floodwater irrigation systems were developed in large population centers like Chaco Canyon

and Mesa Verde the fields watered by these systems constituted a small fraction of the lands planted (Armillas, 1961). These fields were used for special crops such as squash, beans, and ceremonial corn, and for additional maize to serve as insurance in case of excessive crop losses in the main fields still farmed by simpler dry and floodwater methods.

Anasazi Abandonment

At various times during the "classic" stage of Anasazi development the areas of major population concentration were abandoned. The first to be deserted was the Chaco Canyon in northwestern New Mexico, an area which had been occupied by Anasazi peoples as early as 500 A.D. and had witnessed the transition from Basket-Maker to Pueblo and the elaboration of the Pueblo phase to its classic stage (Wendorf, 1956). It is estimated that the Chaco Canyon was almost completely deserted by its original inhabitants at the end of the 12th century. There is evidence of occasional reoccupation of sites and some construction of a few small sites by Anasazi people at scattered times after 1200; however, these occupations were short-lived with comparatively small populations (Vivian and Mathews, 1964). The great cliff dwellings and other settlements in the extensive Mesa Verde-San Juan area, another region of long Anasazi occupation and development, were depopulated by the end of the 13th century. Other areas of population concentration in northeastern Arizona, such as Canyon de Chelly and the settlements in the Flagstaff area, were also in the process of abandonment during the 13th and 14th centuries. The evidence suggests that these areas were not reoccupied to any extent by Anasazi peoples and remained deserted until the entrance of the Navajo and later the Anglos (Jett, 1964; Vivian and Mathews, 1964).

Accounting for this mass abandonment and tracing the migration of these people has been one of the major problem areas for continuing research in Southwest Archaeology. Over the years many theories and speculations have been advanced to explain the complete abandonment of the core areas of Anasazi culture, apparently at the height of its development. Most of these theories have one point in common, however; that is, whatever is being proposed as the basic cause of abandonment is a cause because it had a harmful to disastrous effect on agriculture, the economic base of Anasazi culture.

The "Great Drought" theory developed by Douglass and accepted by others (e.g., Dozier) is one of the most prominent. Its premise is that there was a prolonged dry period in the San Juan region beginning around 1215 which reached severe drought proportions by 1275 and lasted until approximately 1300. Agriculture was made increasingly difficult until the populations of the pueblos in the area were forced to abandon their homes in search of more favorable farming areas. Douglass based his theory on evidence from tree-ring studies which show narrower rings for the postulated drought period than in periods of normal precipitation (Jett, 1964).

Another theory given much weight by other anthropologists is that of arroyo-cutting developed largely by Bryan (1941) and amplified by Reed (1944). This theory contends that, as a result of climatic changes such as prolonged drought or a change in the precipitation pattern, a new cycle of erosion was begun. The farmlands of many Anasazi communities were cut by deep arroyos which eventually made farming by the prevalent floodwater irrigation methods impossible. The techniques developed to compensate for the change in precipitation pattern that occurred earlier were insufficient to deal with the effects of a prolonged drought as well. The water table was lowered,

ground vegetation destroyed, the soil's ability to hold moisture was reduced, and the runoff from sporadic showers concentrated in the stream beds and arroyos deepening these natural water channels and sometimes cutting new ones. Many years of this pattern could result in the effective destruction of farmlands and the abandonment of large communities in search of new homes with more favorable agricultural conditions.

The "nomadic raider" theory proposed by Gladwin and others is one that has gained some support. This theory maintains that the Anasazi were forced to abandon their homes due to the harrassment and pressures put on them by aggressive bands of nomads, probably of Canadian Athapaskan origin, who were then recent arrivals in the Southwest. It is conjectured that these people were the ancestors of the war-like Navajo and Apache tribes who were very troublesome to the Pueblos and Spanish in the historic period (Jett, 1964).

Linton, an opponent of the "nomadic raider" theory, has proposed another alternative explanation for the abandonment of Anasazi communities. He suggests that perhaps the trend to larger towns with corresponding population concentrations was, in part, related to defense requirements due to conflicts between towns over limited land and water resources. He further suggests that subsequent population growth coupled with the drought conditions of the late 13th century called for more intensive use of local agricultural resources with a corresponding intensification of inter-pueblo conflict, and thereby forced the migration initially of the weaker groups. However, eventually the groups remaining were also forced to leave because of the exhaustion and diminution of local agricultural resources (Linton, 1944).

There are several other causes proposed for the abandonment of Anasazi settlements in the 13th and 14th centuries (Jett, 1964). Some involve the possibility of localized climatic and environmental changes such as a change in temperature pattern from warm to cooler making the growing season of some pueblo sites, especially those at higher elevations, too short for the cultivation of maize. Another cause cited in the literature involves the possibility of chemical changes in the water supply (too alkaline or saline) of some pueblos making agriculture impossible. Another speculation is that perhaps some large pueblo towns, because of unsanitary conditions and overcrowding, were the victims of disease and epidemics which forced their migration. Lastly, there has been some speculation that perhaps there were no externally caused factors for some of the migrations, but rather that they were motivated by religious sentiments within the community. It has been suggested that some pueblo groups may have believed that they were called upon by their gods to find new homes. This kind of speculation is usually prompted by indications that the migrations were orderly and planned, and by the notion that groups, especially primitive ones, may make major decisions on just such grounds.

Although some of these theories have been largely discounted, the epidemic theory for example, others are still the subject of much debate. In his article surveying the various theories proposed for the complete abandonment of the San Juan Anasazi area Jett maintains that no one theory is capable of explaining the entire process. One reason for this being that abandonment was a gradual process which covered approximately 200-300 years, making it highly unlikely that one physical phenomenon could account for every case of abandonment. Instead different reasons may be responsible for

abandonments in different areas at different times. Also multiple as opposed to single causes are frequently involved.

Jett, however, is still trying to find a unifying common factor that may be involved in most if not every case. His choice for this factor is the nomadic raider theory. This theory could play that role if there were sufficient evidence to prove that there were, indeed, groups of nomads in the area as early as the beginning of the 12th century. The earliest dates that have been established for the presence of these groups in the Southwest is in the mid-14th century (Ellis, 1964), too late to be responsible for either the Chaco Canyon or the Mesa Verde abandonments but possibly early enough to have been a factor in the abandonment of some northeastern Arizona pueblos. The presence of hostile nomads after the mid-14th century could also have been a factor in the Anasazi's failure to reoccupy the abandoned areas.

At this point arroyo-cutting is cited as the primary cause of the abandonment of the Chaco Canyon area (Vivian, 1970), while the extensive drought of 1275-1300 and the continuing effects of arroyo-cutting in canyon and valley bottoms are believed to have been the major cause of abandonment of the Mesa Verde region (Herold, 1961). Other factors cited earlier in various combinations are responsible for migrations in other Anasazi areas. The important point for this discussion is that the abandonment of some of the major areas of Anasazi concentration was the result of environmental shifts which seriously affected the agricultural water supply. The prolonged effects of these changes were so severe that even the use of water control techniques and drought-resistant varieties of maize were insufficient to permit agriculture on the scale needed to support the expanded populations

of these areas. Furthermore, the Anasazi were more committed than ever to a sedentary agricultural lifestyle and reversion to a pattern more dependent on hunting and gathering was not practical for the whole population (Hill, 1970). The factors making agriculture difficult would also have an effect on the availability of wild foods. The Anasazi fell back on their tradition of mobility and left the San Juan area to establish new communities in areas better suited to their agricultural lifestyle.

Resettlement of the Anasazi

It is generally believed that the Anasazi of the San Juan region migrated to other areas of Anasazi influence such as the Hopi country in Arizona, the Zuni and Acoma districts in northwest New Mexico, and the Rio Grande Basin. The migration and resettlement of the Anasazi were events which took place over many years and there are indications that there were many temporary, short-lived settlements before they were established in the sites in which they were discovered by the Spanish (Wendorf and Reed, 1955).

Of the present day Pueblo groups that are the subject of this study, most are located in the Upper and Middle Rio Grande Valley. Although this area is considered to fall under the Anasazi influence it lagged behind the developments in the San Juan region during the Basket-Maker and transitional Pueblo phases. McGregor (1965) indicates that the first major culture change in the Upper Rio Grande and Pecos River areas from a Desert Culture type occurred around 400 A.D. in the form of an early stage Basket-Maker culture with some Mogollon-related traits. The Basket-Maker stage of Anasazi culture persisted in the Rio Grande area until after 900 A.D. At this time, when surface masonry homes were completely replacing the pit-house in the core Anasazi areas, pit-houses were built exclusively in the Rio Grande area

and were still being used by 1100 A.D. although surface adobe dwellings had been introduced. The Upper Rio Grande was a sparsely populated region until after the migration of the more advanced Anasazi peoples from the San Juan region. McGregor points out that there is a general lack of sites for the period 700-900, more sites for the 900-1100 period, but still not comparable to the number of sites found in other Anasazi areas. He notes that this has raised speculation among some investigators that nomadic groups may have been present at this early date and presented a danger to settlement in the area. McGregor does not necessarily agree with this contention, but he observes that, "The abundance of sites of this period to the immediate north and west, and the strikingly high development of architecture there, would seem to indicate that something was keeping these people out of the northern Rio Grande Valley." (McGregor, pp. 254-55).

Other students of Southwestern culture history have agreed with McGregor's contention but do not hold nomadic raiders responsible. They believed that it was the area's limited potential for pre-irrigation farming that kept the Rio Grande Basin region from being a center of Anasazi cultural development. (Carter, 1945). Carter has shown that there are several factors involved in successful dry or floodwater farming in the Southwest. Total annual precipitation is one factor, but the distribution of that rainfall over the year is as important as the total amount. The length of the growing season, the range of temperature extremes, and the particular varieties of maize, beans, or squash to be grown are also important. The Rio Grande Valley itself is highly unsuited to dry farming. The average annual rainfall in the valley is generally around 10 inches. The greater portion of this rainfall comes during the summer and early fall months which is necessary for

maturation of maize but there is insufficient winter and spring precipitation to sustain the initial stages of maize growth. Furthermore, the growing season is not long enough to wait for the summer rains before planting (Carter, 1945).

As we have noted before there was very little irrigation practiced by the Anasazi in their former sites and it would appear, therefore, unlikely that they would have migrated to the Rio Grande to utilize its irrigation potential. In fact, they did not by and large relocate in the valley bottom itself but rather most of the post-1200 sites are found in the plateau country and canyon lands a few miles from the river and its tributaries (Carter, 1945; Schoenwetter and Dittert, 1968). These sites were somewhat better suited for agriculture in terms of precipitation and temperature than the valleys, but, more importantly, they were suitable for the floodwater farming methods developed in other Anasazi areas. Armillas has suggested that the reason the Anasazi migrated to the Rio Grande Basin in such numbers was because its topography was less susceptible to disastrous arroyo-cutting and, therefore, was highly attractive to floodwater farmers (Armillas, 1961).

The problem of water supply and settlement patterns in the prehistoric Southwest is more complex than it first appears on the surface. One assumes that a relatively stable reliable source of water is needed for the survival of primitive agricultural groups and then looks to those areas of traditionally stable water supply either in the form of permanent rivers, streams and springs or heavy annual rainfall for centers of prehistoric cultural development. Of course, one is not surprised to find concentrations of population and cultural development in areas like the Mesa Verde or the Gila and Salt River basins. However, we are surprised to learn that an area

such as the Rio Grande Valley with its great river and many tributaries was late in being settled while areas like the Hopi, Zuni and Acoma country were occupied sooner and have remained continuously occupied by Pueblo peoples. If water supply is an important factor in the development of these cultures why would some groups choose to live in what appears to be an unfavorable site when more favorable locations are available and when these people have shown no particular hesitation about moving in the past?

Part of the answer would seem to be that in the Southwest the settlement patterns of prehistoric farmers are based on the agricultural potential of an area coupled with the level of agricultural technology used by the people at a given time. The earliest farmers could practice agriculture only where there was sufficient moisture from both rainfall and spring flooding to permit dry farming. The mountainous country of the Mogollon, the mesa and canyon country of the Mesa Verde area, and the high valley of the San Pedro River in southern Arizona were more appropriate for this kind of farming than the valleys of major rivers which tend to have low precipitation poorly distributed. Also, in the earliest stages of farming, hunting and gathering still occupied a major role in the food procurement process and river valleys were too far away from the wild food sources of the mountains and mesa country.

As agriculture began to assume a greater role in the subsistence pattern of the Anasazi, more knowledge about agriculture was gained, and improved techniques were developed, areas not previously useful would become inhabitable by agriculturalists. Areas that appear to have an insufficient water supply may be made agriculturally productive by the development of techniques adapted specifically to that area. The sand dune agriculture of the

Hopi is such a technique (Jennings, 1968). The Hopi learned that the shallow sand dunes on the fields below the mesas hold moisture for a considerable time. With deep planting, up to 12", the seeds will germinate and have enough moisture to survive the spring drought until the summer rains and floods arrive bringing enough water for maturation. On the other hand, an area like the Rio Grande Basin which has a large permanent water supply is useless to primitive agriculturalists without the knowledge of either river and stream irrigation or floodwater irrigation practices. In the case of the Anasazi, the floodwater techniques developed to cope with the multiple factors of increased dependence on agriculture, population growth, and shifts in local climatic conditions were applicable to some parts of the Rio Grande Basin region in New Mexico. When conditions became too severe to permit the continuance of agricultural communities in the San Juan region the Anasazi abandoned their homes and migrated to areas where their agricultural technology was appropriate, including the Rio Grande area.

The Rio Grande Pueblos

Since the Rio Grande region was the main recipient of Anasazi migrations there has been much interest in identifying specific Rio Grande Pueblos with specific Anasazi groups. The problems in this area are great because the Anasazi of the abandoned areas differed from each other as well as from the Rio Grande Anasazi. Obviously there were many changes that took place after resettlement in the Rio Grande Valley with diffusion and sharing of cultural traits among all the Rio Grande Pueblos. Wendorf and Reed note that during the period 1325-1600 which they classify as the "classic" stage of Rio Grande Anasazi culture, "there was a general florescence of material culture," and that, "the major stimulus for this development lay within the

Pueblo culture itself and was, in part, a result of the various and slightly diverse elements which found their way into this area around A.D. 1300." (Wendorf and Reed, p.153). It is believed that the Rio Grande Anasazi were still in the midst of their cultural flowering and perhaps on the brink of new cultural breakthroughs and developments when they were discovered by the Spanish in 1540 (Dozier, 1970). This process of continuous cultural development was disrupted and profoundly altered by the introduction of permanent Spanish settlements in the early 17th century.

It is not known for certain whether or not river and stream irrigation was part of the cultural development of this period, and, if it did exist, what was the extent of its use among the Rio Grande Pueblos. Some students of Southwestern prehistory and ethnography believe that the use of river and stream irrigation was widespread and flourishing before the entrance of the Spanish and have built tentative theories relating the differences between the Rio Grande and the Western Pueblos to differing farming practices, the Rio Grande Pueblos relying on river irrigation and the Western Pueblos depending on precipitation for dry and floodwater farming (Dozier, 1970; Eggan, 1950; Wittfogel and Goldfrank, 1943). They base these beliefs primarily on scattered references to irrigation practices in the narratives of the early Spanish explorers and in Pueblo mythology (Wittfogel and Goldfrank, 1943). However, other archaeologists more familiar with evidence of agricultural practices are not convinced about the extent of the use of irrigation, especially river irrigation, before the arrival of Spanish settlers (Bryan, 1929; Carter, 1945; Stewart, 1940; Woodbury, 1961b). They base their opinions also on various historical narratives and on archaeological data from abandoned and existent pueblos.

Most of the references cited by those that believe in pre-Spanish use of river irrigation are from Zuni and Acoma, two Western Pueblos. The references don't mention the specific source of these irrigation systems but it is likely that they were small springs and streams rather than a permanent river. Even into very recent times (1940's) the Zuni were primarily dependent on floodwater irrigation practices similar to those described for the prehistoric Anasazi (Stewart, 1940). The evidence from mythological references is subject to doubt unless it can be backed up by archaeological evidence.

Those that are more doubtful about river irrigation cite references that indicate that the Spanish settlers put the Pueblos to work immediately on the construction of irrigation works (Stewart, 1940). Of course, they would have had to build their own systems since they did not move in with the Pueblos, but there are indications that the size of the systems was seen as unusual by the Pueblos. There is little evidence concerning the presence of irrigation systems in the pueblos that were later abandoned (of the 70-80 pueblos in 1540 only 19 are left and there is some difficulty in determining their longevity). Also, there is a difficult problem in determining the age of the irrigation systems of the existent pueblos because so many changes have been made and because the Rio Grande Pueblos have been quite conservative in the past and reluctant to allow archaeological research in their communities. Until more evidence is available on the extent of pre-Spanish irrigation it will have to be assumed that the use of river and stream irrigation systems was not a common widespread practice among the New Mexico Pueblos.

Spanish Settlement in New Mexico

The first Spanish explorers arrived in present day New Mexico in 1540 searching for the rumored Seven Cities of Cibola, the golden cities. Instead they found the Pueblo Indians inhabiting between 70 to 80 villages of varying size and population scattered along the Rio Grande and in the tributary areas east and west of the river (Miller, 1941). The people of these villages were the descendants of the original Anasazi occupation, the San Juan Anasazi migrations, and Mogollon migrations from the south. They were a relatively prosperous people with solid well-built adobe and masonry homes, attractive cotton clothing, and plentiful food supplies from their fields; but they were a far cry from the wealthy people with homes of gold that Coronado and his men had expected to find.

The Coronado expedition spent two years wandering over the Southwest looking for the Seven Cities. They finally gave up and went home to Mexico leaving several priests behind with the Pueblos. Although the Pueblos were basically friendly to the Spanish they resented the priests who tried to interfere with their religion and promptly killed them once the soldiers had gone. With the exception of two or three small expeditions sent to check on the condition of the priests and to explore the area further for possible settlement the Pueblos were essentially left alone until 1598 when Onate was given royal authority to establish a settlement, exploit the natural wealth of the area, and to convert the Indians. In the spring of that year he lead a party of colonists, soldiers, priests, and Mexican Indian slaves up the Rio Grande extracting promises of loyalty and obedience from the pueblos as they advanced up the valley (Dozier, 1970, Spicer, 1954,1962).

The original Spanish settlement in New Mexico was founded at San Gabriel near present day San Juan Pueblo. Onate lead parties of soldiers from the settlement to gain the submission of other outlying pueblos, but at Acoma they were met with determined resistance. After a bloody battle the Acomas were defeated and cruelly punished as an example to other pueblos who might think of resisting the Spanish (Dozier, 1970; Spicer, 1962). Settlement of the Rio Grande Valley progressed rapidly although there were only a few settlers. More priests were sent from Mexico to convert the Pueblos and by 1640 there was a church in almost every village although there were not enough priests for each one.

The combination of rapid changes that the Pueblos were put through by the Spanish, forced conversion to Christianity, harsh treatment and forced labor by the priests and soldiers, built up much resentment among the Pueblos. In 1680 the Pueblos united, rose up in violent revolt against the Spanish, and succeeded in driving them out of New Mexico (Dozier, 1970; Reed, 1954; Spicer, 1954, 1962). This was the first time the disconnected pueblos had been able to work together, but the resentment against the common enemy was strong enough to overcome their differences. Many people were killed and those that survived fled to El Paso. Some of the southern pueblos below Isleta gave aid to the fleeing Spanish and several pueblos were abandoned in fear of both the Spanish and the revolting pueblos. Scattered attempts by the Spanish were made to retake the former settlements but none were successful until 1692. The Pueblos were unable to maintain the unity and organization they had developed for the revolt and succumbed to the Spanish reconquest. In the process more pueblos were abandoned and shifts in population took place. Some Pueblos, unable to tolerate the idea of Spanish

domination fled to the Western pueblos which had suffered less at the hands of the Spanish since the initial contacts because of their distance from the main area of settlement in the Rio Grande Valley area. Others founded a new pueblo, Laguna, to the west of the river. Still others were so decimated by the fighting that the survivors left their homes and moved in with other Rio Grande Pueblos.

The Pueblo Revolt of 1680 was the first and last time that the Rio Grande Pueblos as a group attempted to throw out the Spanish. After the Reconquest there were scattered rebellions at individual pueblos but they were quickly put down. The Spanish took on a more lenient attitude toward the Pueblos and some of the worst abuses of the first century of Spanish settlement in New Mexico were removed. In particular, when the Pueblo's outwardly accepted Catholicism the harsh repression of their native religion was diminished and they developed the curious mixture of Christianity and their own religion that is practiced today (Dozier, 1970).

As far as the economic system of the Pueblos is concerned, the arrival of the Spanish produced few substantial changes; the Pueblos continued to live under an agricultural subsistence economy. The Spanish did, however, introduce several improvements to that subsistence pattern (Dozier, 1970; Spicer, 1962). They brought many new crops including fruits, vegetables, and grains that the Pueblos had not seen before. The Spanish also brought domestic animals which the Pueblos did not have, such as horses, cattle, goats, and sheep, and thereby introduced a new facet to the agricultural base, ranching. They also brought better tools of metal, and improved agricultural techniques including large-scale irrigation of farmlands. Essentially the Spanish settlements encroached very little on the land and water

resources of the Pueblos because under Spanish law the rights of the Pueblos to their land was recognized and formalized (Logan, 1961).

After the revolt the Pueblos and Spanish managed to live peacefully, if not cordially, and offered each other mutual aid and support in some areas. There are several instances of shared irrigation works and cooperation in the distribution of water from adjacent streams between Spanish and Pueblos (Adams and Chavez, 1956). By the end of the 17th century Apache and Navajo raiders on horseback had become a real problem to all sedentary people in the Southwest. One reason that more Pueblos did not leave their homes to get away from the Spanish may have been the danger presented by these hostile tribes (Reed, 1954). The Pueblos along the Rio Grande were better able to defend themselves with the help of the Spanish than were isolated pueblos. There was a trade-off between the disagreeable Spanish and the equally, if not more, disagreeable Apache and Navajo. Some outlying pueblos chose to remain isolated and defend themselves against the raiders alone, but as the raids became more frequent and climatic conditions fluctuated (there were several long periods of drought during the 17th and 18th centuries, Dozier, 1970; Spicer, 1962) the prospects of joining the Pueblos and Spanish along the Rio Grande became more inviting. In a situation of increased raids and unstable climatic conditions the Rio Grande Pueblos with irrigation and the Spanish to help with defense were better off than isolated pueblos without either.

In some studies of the Pueblos of the Rio Grande the idea is often expressed that the Pueblos taught the Spanish about irrigation farming, but that idea can be refuted. The Spanish, unlike other Europeans, were familiar with arid and semi-arid environments and irrigation farming, both

from their experiences in their native Spain and in Mexico (Logan, 1961). To them the Southwest did not seem the arid wasteland that later European and Anglo settlers saw it as. They recognized its potential and knew how to use it, that is, in much the same way the Pueblos did. Furthermore, most of the early settlers of New Mexico were not the great landowning Dons but peasants who lived in small villages and farmed the land they owned collectively, providing themselves with the things they needed from what the land offered, in a manner very similar to the Pueblos. Therefore, it can be seen that aside from relatively minor changes in their subsistence inventory and a more important change to greater dependence on irrigation farming the economic system of the Pueblos was not greatly altered by the settlement of the Spanish.

The presence of the Spanish and the position of dominance they exercised over the Pueblos did produce important changes in the patterns of social organization of the Pueblos. Some anthropologists have developed a theory explaining certain differences in the basic social organization patterns of the Western and Rio Grande Pueblos in terms of the type of farming and water supply each used. The Rio Grande Pueblos have a more centralized authority structure; a more highly integrated society in terms of economy, religion, and government; and are more communally oriented than the Western Pueblos. The religious emphasis of the two groups is different also, the Rio Grande Pueblos placing importance on healing while the Western Pueblos stress rainmaking ceremonies. It is held that the Rio Grande Pueblos are more centralized and integrated because of the need for community-wide cooperation in the building and maintenance of the irrigation systems. The Western Pueblos are seen as less community oriented because their fields are farmed and owned by individual clans and the farm methods used do not require the same type

of coordination as the Rio Grande Pueblos (Dozier, 1970; Eggan, 1950).

These contentions may be true but whether or not the observed differences are causally related to agricultural water supply is uncertain. It has been shown that irrigation was not the prevalent agricultural method of the New Mexico pueblos before the Spanish arrived, and that the Spanish introduced large-scale irrigation into the Rio Grande Valley area. The Spanish also imposed a governmental superstructure on the pueblos to make them conform to the traditional form of Spanish town and village government, and among the officials included in this structure are officials to oversee and coordinate the maintenance and operation of the irrigation systems (Aberle, 1948). It has also been shown that after their first efforts to extract token allegiance the Spanish largely left the Western Pueblos to themselves because their locations were less desirable than the Rio Grande Valley where they concentrated their settlements.(Spicer, 1962). It seems more likely that these differences are due to the change in water use pattern and governmental structure imposed on the Rio Grande Pueblos by the Spanish and to the lack of Spanish influence on the Western Pueblos. It can be argued that the potential for these differences existed even if the Spanish had not come because of the basic difference in water availability between the two. The Rio Grande Pueblos might have developed a dependence on irrigation farming eventually without the impact of the Spanish but the authority structure developed to direct it might have been very different. If one accepts the notion that without wide-spread irrigation the New Mexico pueblos, Rio Grande and Western, were basically similar in agricultural technology and social organization, then it would appear safe to say that the influence of the Spanish coupled with the water availability situation of the Rio Grande Pueblos was responsible for some of the differences observed between the Rio Grande and Western Pueblos.

Anglo Settlement in New Mexico

It has been seen that although the presence of the Spanish produced some changes in the social institutions of the Rio Grande Pueblos the basic economic pattern of all New Mexico Pueblos was little changed. From the time of the Reconquest to the period of Mexican rule the Spanish settlers and the Pueblos were basically compatible neighbors in terms of economic adaptation to the environment and its fluctuations. Although the Spanish population outnumbered the Pueblos by the last quarter of the 18th Century the adverse effect on the environment was minimal (Logan, 1961).

In 1848 the New Mexico territory was taken over by the United States as part of the spoils of the Mexican-American War. From this point on some of the most significant external disruptions and changes in Pueblo life occurred. The increase in the Anglo population, which was very slow until after the Civil War when there was an influx of settlers, ranchers and homesteaders, coupled with the steadily growing Spanish or Hispano population (as Dozier refers to them) placed heavy demands on the natural resources of New Mexico (Harper, et.al.,1943).

When the United States took over the New Mexico territory the government was obliged under the conditions of the Treaty of Guadalupe Hidalgo to acknowledge the prior land and water rights of the inhabitants including the Pueblos (Cohen, 1942). However, settling title to Indian lands proved to be a complicated matter which took nearly one hundred years to resolve. Formal land grants to the individual pueblos had been issued by the Spanish government in the 17th Century and were protected and honored until the weakening and final overthrow of the Spanish in the early 19th Century. The Pueblo land grants included thousands of acres of desirable farmlands in the Rio Grande Valley. The Hispano population was growing rapidly and needed new lands which were sometimes acquired

by squatters taking up farming and ranching activities on Pueblo lands. These squatters later claimed to U.S. authorities that they or their ancestors had bought the land from the Pueblos (Dozier, 1970).

The land problem of the Pueblos was further complicated by their uncertain legal status in the eyes of the U.S. government. Under Spanish rule the Pueblos were wards of the Crown and were not permitted to sell their grant lands. Under Mexican authority they were made Mexican citizens with full rights including the right to sell their lands. According to the Treaty of Guadalupe Hidalgo all former Mexican citizens (including the Pueblo Indians) were to become U.S. citizens and their property rights protected. However, in the United States all Indian groups were considered wards of the government which entitled them to the services of the Indian Bureau. In addition, reservation lands were set up for them which could not be disposed of without government permission. The health, education and agricultural services of the U.S. Indian Bureau were extended to the Pueblos soon after the U.S. takeover, but their legal status in terms of their lands remained ambiguous. In several cases the territorial courts and the U.S. Supreme Court (U.S. vs. Joseph) ruled that since the Pueblos had been Mexican citizens and were sedentary farmers they should have free title to their land and the right to dispose of it as they saw fit (Cohen, 1942). However, the majority of lost Pueblo grant lands were lost by illegal means (direct takeover by Hispano and Anglo squatters and sale by the squatters to others) rather than sale by the Pueblos (Dozier, 1970).

The Pueblos were engaged in disputes to regain expropriated grant lands for several decades. Finally, in 1913 friends of the Pueblos again took the case of the Pueblos' land status to the Supreme Court. In the case of the U.S. vs. Sandoval the Court reversed its previous ruling and stated that the Pueblos were, and should always have been, wards of the government like other Indian groups in the United States (Cohen, 1942). This meant that Pueblo lands

could not be disposed of without government permission and, therefore, any loss of grant land in the past was illegal and must be returned to the Pueblos.

The Pueblos now had a firm legal basis for their land claims but the disputes were not over. In the early 1920's Senator Bursum of New Mexico introduced a bill in the Congress to quiet title to the Anglo and Hispano claims to Pueblo lands. Friends of the Pueblos waged a successful fight to defeat the bill and to establish a federal authority, the Pueblo Lands Board, to settle the conflicting land claims (Brayer, 1938). By the mid-1930's the claims were settled. Where it was impractical to give back original grant lands to the Pueblos monetary compensation was made and new lands purchased, while Anglo and Hispano claimants were compensated for the value of improvements made on Pueblo lands that were returned.

The settlement of the Pueblos land problems, however, was not the final solution to their economic problems. During the period of the land conflicts the economic situation confronting the Pueblos had changed drastically. They were no longer in the position of being faced with changes in the environment that could be adapted to in traditional ways. The environment now included social and political factors that were more pervasive and inescapable than any they had faced up to then. They had been forced to change from a self-sufficient subsistence agriculture economy to a credit and cash income economy imposed by the Anglos in which their traditional agriculture played an increasingly smaller role (Aberle, 1948). In whatever economic pursuits they were engaged they had to compete for needed resources with more knowledgeable and powerful competitors.

The conditions which produced the intense competition for land resources also involved the Pueblos in competition for water resources. The problem of Pueblo Indian water rights, however, was more complex than the land situation and, as yet, is unresolved to the Pueblos satisfaction.

It has long been recognized in New Mexico that the Pueblos have a prior historic right to use of waters that run through or border their lands, but the nature and extent of that right has not been adjudicated by the courts as have other water rights based on prior use (Rosenfelt, 1969). In the past disputes involving Indian water rights have been settled in federal courts on the basis of the Winters Doctrine which holds that American Indians have prior water rights which entitle them to a sufficient amount of water to maintain a permanent home on reservation lands. This has been further interpreted to mean enough water is guaranteed by the U.S. government to irrigate Indian farmlands (Cohen, 1942). This principle has been applied to the Pueblos of New Mexico, but in practice their water rights have also been subject to the doctrine of useful application; i.e., if water rights are not utilized for a period of four years or more they are subject to redistribution by the state.

It has been noted earlier in this report that agriculture in the Pueblo economy has played an increasingly small role since the 1940's. Although several Pueblos are participants, with federal assistance, in the Middle Rio Grande Conservancy District's irrigation project use a large proportion of their farmlands and water rights, the majority of the Pueblos are faced with a situation in which they are farming less, using less water and, therefore, are in danger of losing some of their water rights (Rosenfelt, 1969; Veeder, 1969).

The Pueblos would like to have the matter of their water rights settled, but there is intense disagreement on how this should be done. Some Pueblo people feel, with the support of some legal authorities (Veeder, 1969), that their water rights are always first and inalienable, and that their use should not be restricted by the state. Others, while agreeing in principle, feel that this position is impractical in the actual situation and would like to have

their water rights adjudicated by the federal courts to determine their precise nature and extent. The Pueblos of Nambe, Pojoaque, Tesuque, and San Ildefonso are currently involved in litigation for this purpose (Rosenfelt, 1969), but this tactic has produced little satisfaction to the present time. The process has been stalled over the question of whether or not the Winters Doctrine applies to the Pueblos, but in the early stages of the litigation Winters was recognized as the basis for a determination. At that time the primary point of contention centered on whether or not potentially irrigable acreage should be included in the determination and, if so, what criteria should be used to determine the number of potentially irrigable acres (Rosenfelt, 1969). Much time, effort, and money was expended for engineering studies to estimate the potential irrigated farmlands on Pueblo lands. However, in 1973 the federal district court tentatively ruled that Winters does not apply to the Pueblos because the history of their relationship with the U.S. government has not followed the typical pattern. This ruling is being appealed by the Pueblos and a final ruling is expected to be made in early 1974; but whatever the outcome on the Winters issue, the adjudication process will still be far from ended.

The Pueblos today are in a very difficult situation in many respects. Major decisions have to be made concerning their future and the kind of life they want to lead (Meaders, 1962; Smith, 1969). How can they improve their economic position and still maintain those aspects of their traditional culture they consider most important? Restoring the traditional subsistence agriculture pattern is impractical and unlikely. The outside world with its material goods is already too great a part of modern village life to go back to a more austere life. Furthermore, commerical agriculture is unfeasible given the current land tenure system in which each individual or family holds small scattered plots and where

there is not enough arable land to support more than a small fraction of each pueblo's population with farming as a full-time occupation (Smith, 1969).

The Pueblos consider the matter of their water rights a top priority issue because in the Southwest, where water is an essential resource for any economic undertaking, having a known, reliable supply of water would provide a sound base to begin planning future economic development. However, many other important decisions must also be made simultaneously, and settlement of the water issue should not be seen as a cure-all for Pueblo economic problems. The issue of capital sources, both monetary and human, is equally important. Where are they to come from and how will they be used are questions that also have to be answered. The current Pueblo economic situation is complex because the number of environmental factors that must be recognized and dealt with is greater than ever before in their history. Water availability is one of many factors, social, political and physical, with which they have to contend.

Population, Growth, and Water Use Technology

The following section will attempt to develop an analytical framework for understanding both the role of water use technology (essentially agricultural utilization) in the historical development of Pueblo cultures in the Southwest, and the essential differences between this historical development and the complex set of economic and social forces which currently face Pueblo cultures imbedded in a modern industrial economy.

The historical record for agricultural technology is presented in Figure 1. The distinct levels of technology prior to the arrival of the Spanish fall into four main groups: (i) dry farming, (ii) simple floodwater, (iii) improved floodwater (systems for retaining, storing, and directing floodwaters), and (iv) river irrigation. The last two of these reached seemingly equal levels of social

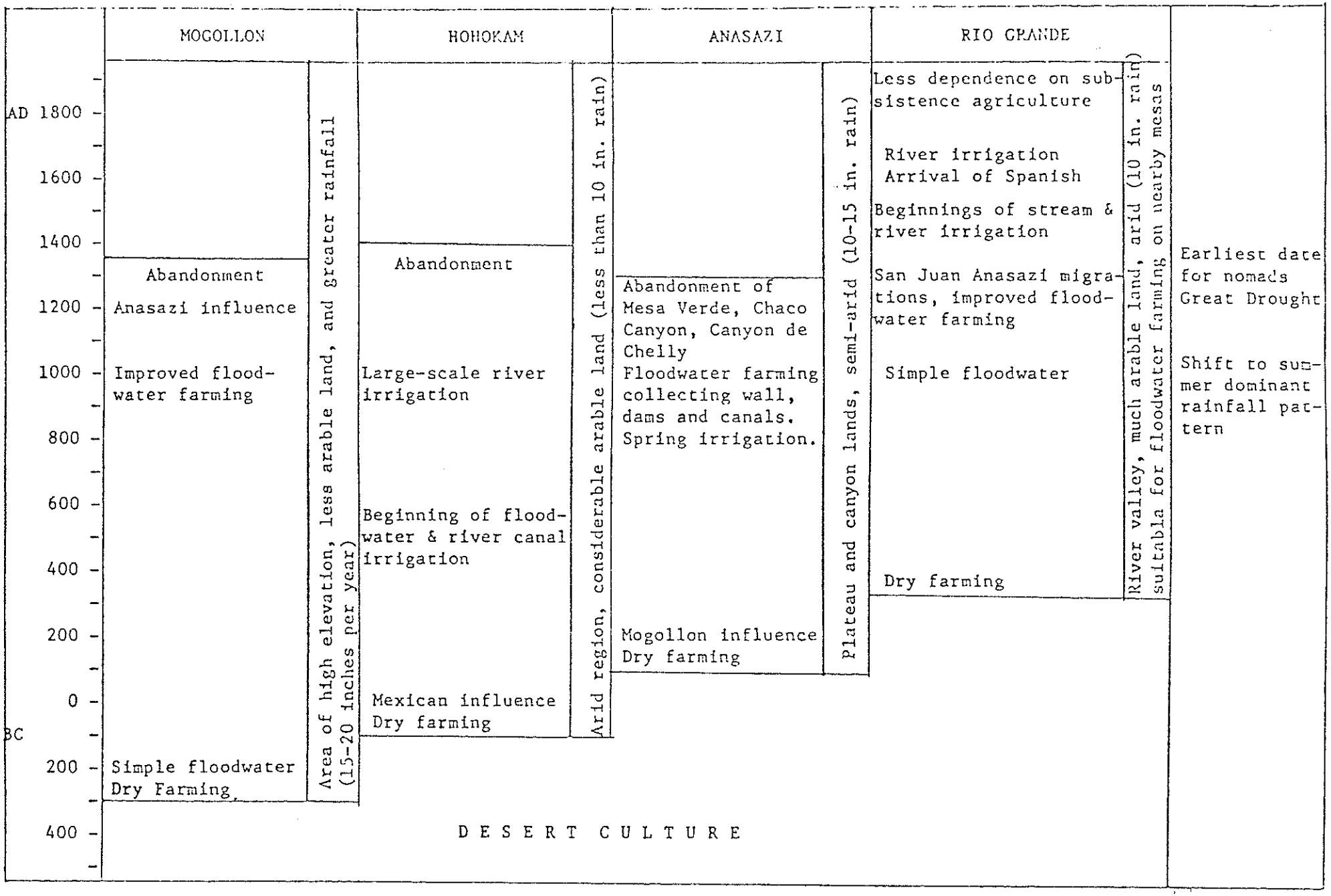
MOGOLLON
HOHOKAM
ANASAZI
RIO GRANDE
AD 1800
1600
1400
1200
1000
800
600
400
200
0
BC
200
400
Abandonment
Anasazi influence
Improved floodwater farming
Simple floodwater Dry Farming
Area of high elevation, less arable land, and greater rainfall (15-20 inches per year)
Abandonment
Large-scale river irrigation
Beginning of floodwater & river canal irrigation
Mexican influence
Dry farming
Arid region, considerable arable land (less than 10 in. rain)
Abandonment of Mesa Verde, Chaco Canyon, Canyon de Chelly
Floodwater farming collecting wall, dams and canals.
Spring irrigation.
Mogollon influence
Dry farming
Plateau and canyon lands, semi-arid (10-15 in. rain)
Less dependence on subsistence agriculture
River irrigation
Arrival of Spanish
Beginnings of stream & river irrigation
San Juan Anasazi migrations, improved floodwater farming
Simple floodwater
Dry farming
River valley, much arable land, arid (10 in. rain) suitable for floodwater farming on nearby mesas
Earliest date for nomads
Great Drought
Shift to summer dominant rainfall pattern
DESERT CULTURE

Figure 1

and technological sophistication in the Anasazi and Hohokam cultures respectively while the Mogollon culture depended only on the more primitive techniques. Some explanation of this pattern should be of use in understanding the lack of extensive river irrigation in the Rio Grande Valley by pueblos at the time of the Spanish arrival.

First, it is important to note climate differences between the regions in which these preceding cultures developed. The Hohokam developed in a truly arid region which could not support extensive population growth by dry farming or simple floodwater methods of agriculture alone. With this in mind, river irrigation can be viewed as the only feasible adaptation to an arid region which could successfully support an advanced culture. The Mogollon culture, in contrast, developed in a region with sufficient rainfall to support such development by a mixture of dry and floodwater farming without the elaborate or sophisticated techniques applied by the Hohokam to utilize water as a scarce resource. Similarly, the Anasazi development of sophisticated methods for conservation and distribution of floodwater through the use of dams, collecting walls, and canal systems can be seen as an adaptation to a semi-arid climate which shifted to a summer dominant precipitation pattern. All of this evidence suggests that the technology of water use was developed primarily in adaptation to particular climate situations and, further, that shifts in climate or population pressure may have stimulated additional adaptation. Technological development in this sense does not seem to determine the patterns of resource use but rather in the long run it appears that technology adapted to particular regional environments.

The second principal feature of the technological developments shown in Figure 1 is the relatively long time period (by modern standards) between major developments or innovations in water use. Similarly, diffusion of knowledge of

these techniques between contemporary Southwestern cultures also seems very poor. These points may seem unnecessarily obvious, however, they are further reflections of one important difference between Pueblo cultures and modern western economic behavior. Technology in modern economic history can be viewed as an exogenous influence which tends to alter patterns of resource utilization. In the historical pattern of Pueblo cultural development, as mentioned above, technology is clearly evolutionary and adaptive to particular environments. Thus, diffusion of technology is of limited usefulness or applicability between differing environments and innovation is likely to be the result of forces on the culture rather than an independent variable.

Under these assumptions the history of the Pueblo cultures in the Rio Grande area becomes more understandable. Due to an arid climate dry and simple floodwater farming could not yield a sufficient agricultural surplus to support an advanced culture. However, with the abandonment by the end of the 14th century of the Anasazi cultures to the north and west, immigration brought a sophisticated technology of floodwater farming, developed partially under environmental stress, to the Rio Grande area. This new technology was suited to the Rio Grande climate, especially to the surrounding mesa country. Thus, development within north central New Mexico can be viewed as the successful introduction of a fortuitously pre-adapted technology. It is unlikely that there was sufficient pressure from population growth or climate shift in the interval from the introduction of advanced floodwater farming to the arrival of the Spanish to necessitate the further adaptation of river irrigation.

Given these somewhat speculative observations we will develop a theoretical model which draws both upon population biology and classical economics to formally demonstrate the essential differences between the roles of technical change and

economic development in primitive and modern economic systems. We will begin by developing the concept of economic surplus and relating this directly to population biology. The necessary notation is as follows:

N_i = population engaged in agricultural technique i,

Y_i = agricultural output from technique i,

w = subsistence wage in output units, and

$S_i = Y_i - wN_i$ = surplus production above subsistence produced by technique i.

Given a particular technique, e.g., dry farming, output (most appropriately maize) can be considered solely as a function of population, N_i, engaged in this technique,

$$Y_i = f_i(N_i) \ldots\ldots f_i'' < 0,$$

assuming that regional land resources, rainfall pattern, etc., are constant over time. Total output increases, of course, at a decreasing rate with additional labor inputs because the suitability of additional acres of land placed in production with additional labor to dry farming must decrease (assuming the best land is used first). We can then determine surplus production over subsistence (S_i) solely as a function of population size:

$$S_i = f_i(N_i) - wN_i.$$

This derivation is shown graphically in Figure 2. Note that the maximum surplus occurs at population size N_i^* and that the maximum sustainable population occurs where the surplus is zero at $\overline{N}_i$.

Population biology in its more sophisticated formulations considers the concept of maximum sustainable population, taking the rate of population growth at any population size to be proportional to what we have termed surplus production, a concept taken from classical economics. Thus, we can take the time rate of

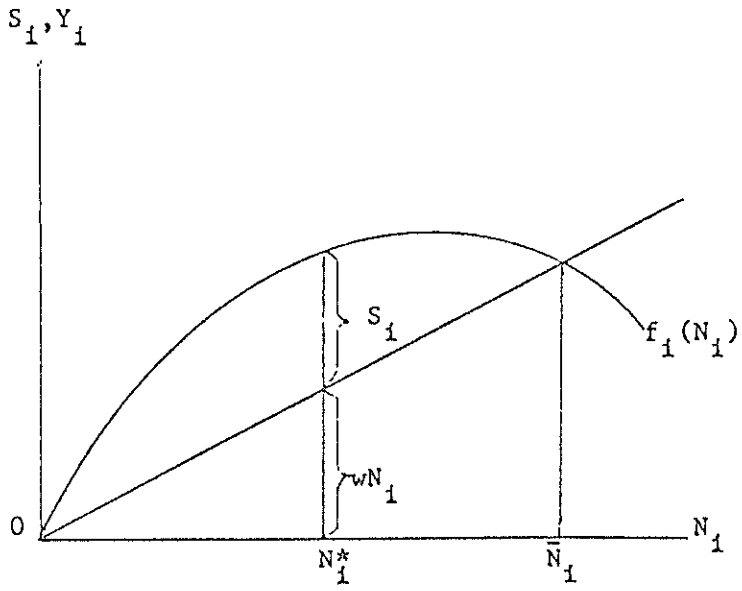

Figure 2

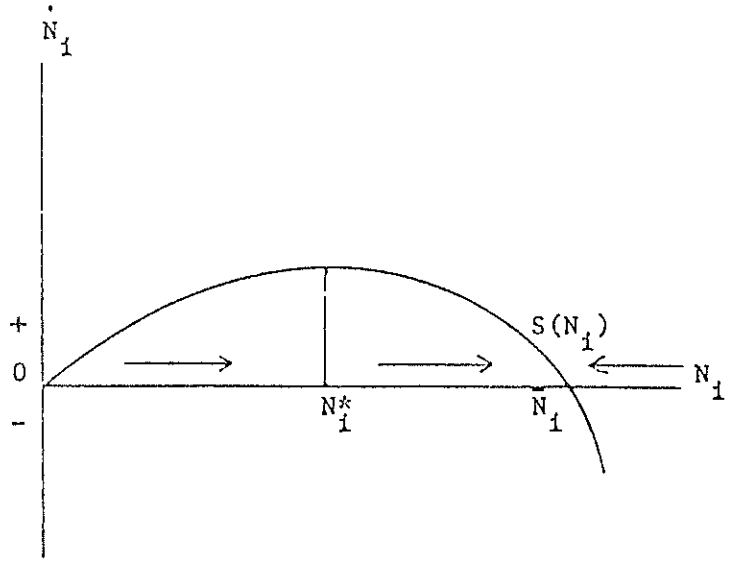

Figure 3

change of population (births minus deaths = $\dot{N}_i$) to be equal to rate of surplus production for a theoretical model:

$$\dot{N}_i = S_i(N_i).$$

This relationship is shown graphically in Figure 3. It is clear that $\bar{N}_i$ represents a stable equilibrium point for a promitive economic community since $N_i < \bar{N}_i$ implies $\dot{N}_i > 0$ and $N_i > \bar{N}_i$ implies $\dot{N}_i < 0$. In the simplest formulation, where a new technique is introduced, N_i will start from zero moving from left to right in Figure 3 increasing until $\bar{N}_i$ is obtained. Note that over this period of dynamic transition and population expansion, the surplus first increases and then declines to zero as maximum sustainable population with the current available techniques is obtained. This model assumes away any mechanism for diverting the surplus in the long run. Modern economic society in essence determines employment by maximizing surplus or, in this particular case where land and labor are the only factors, by maximizing rent (equal to the surplus). In Figures 2 and 3 N_i^* represents the position of employment which maximizes rent or profits to a hypothetical landowner. This number of labor inputs satisfies the condition maximizing real "profit"

$$f'(N) = w$$

(even that labor receives a subsistence wage, w (a wage greater than subsistence causes N_i^* to decrease even further below $\bar{N}_i$). Thus, we can see that a modern economy with ownership of resources, well established property rights, and the profit incentive, tends to establish a mechanism for diverting surplus as profits or rent. A primitive economy on the other hand may have only limited means for such diversion which results in a tendency for population growth up to the maximum sustainable for a given technology. Since cultural complexity and achievement depend on the existence of a substantial surplus maintained by religion, government, or, in modern western society, ownership of productive factors, primitive

economic societies may find population pressures too great to maintain sufficient surpluses in the long run. Thus, if new technological alternatives could not be found in response to increasing population pressures, complex cultures such as those of the Southwestern Pueblos may have at various points faced declining surpluses. Clearly, environmental shifts would increase the stress for adaptation and technological change by further reducing surpluses. Similarly, a combination of overpopulation and environmental stress such as the prolonged drought in the Four Corners area in the 13th century could have reduced surplus production to the point that centralized pueblos such as those of Mesa Verde were no longer viable, forcing migration of the population and a return to a simpler existence. If, on the other hand, a new technological alternative arose from the pressure of population growth or climate shift, a new growth phase could begin, in essence repeating the process shown in Figure 3 for an additional population engaged in the new technique. It is important to note that the introduction of new techniques of agriculture and water use among the Southwestern cultures did not displace old techniques but rather were used in addition to support continued growth of population and culture. Such introduction of new technology would create large transitory surpluses as population expanded through N_i^*. This model then predicts spurts of growth followed by falling surpluses and pressure for new techniques. This contrasts sharply with the modern pattern of continuous technological change supporting a long run expansion both of population and output.

The conclusions of the theoretical analysis for technology and consequently water use in the historical development of Pueblo cultures can be briefly stated as follows: (i) the determination of total "employment" or population engaged in a particular technique is obtained not with the maximization of surplus (marginal economic behavior) but rather by the interaction of technology and population

biology, and (ii) technological change is essentially adaptive rather than exogenous and technological choice is similarly adaptive rather than competitive since inferior techniques will be used along with more advanced ones to support additional population. Both of these results indicate the importance of "non-economic" behavior in understanding the development and current state of Pueblo cultures. Recent literature both in economic anthropology and economic development strongly support this general contention. For example, George Dalton has extensively criticized the use of orthodox economic analysis in explaining patterns of development in primitive societies (Dalton, 1961). We have here focused on those elements relevant for conceptualizing the role of water in Indian economic development. We now turn to implications of this historical development on the current situation.

The Pueblos in New Mexico are currently not fully utilizing their potential water rights. This central fact poses both an intriguing question--why would a scarce resource go unutilized?--and an opportunity for economic development by increased utilization. To answer this question one need only consider the historical behavior pattern now operating in response to the pervasive pressures of a modern economy. Employment of Pueblo Indians in traditional agriculture is limited by the externally imposed opportunity cost of this activity. Thus, the availability of outside employment, increased demand for crafts, and welfare raises the level of economic opportunity above the subsistence level, forcing traditional agricultural pursuits to compete in terms of value and productivity, drastically reducing the scale and consequently water use. One then sees these traditional agricultural pursuits declining throughout the period of Anglo interaction. Unfortunately, no alternative productive use of water appears to have developed within the Pueblo culture, possibly due to lack of adaptive rather than economic

pressures, while traditional agricultural patterns continue at a low level. The problem then becomes one of finding productive uses of water, hopefully consistent with Pueblo cultural values.

Clearly, many general problems of economic development, capital formation, inconsistencies between traditional behavior and economic incentives, and population growth are all relevant and must be considered simultaneously in attempting to increase current water utilization. Although these questions are beyond the scope of this investigation, any further analysis must begin with an understanding of the historical evolution of water use among the Pueblo Indians.

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