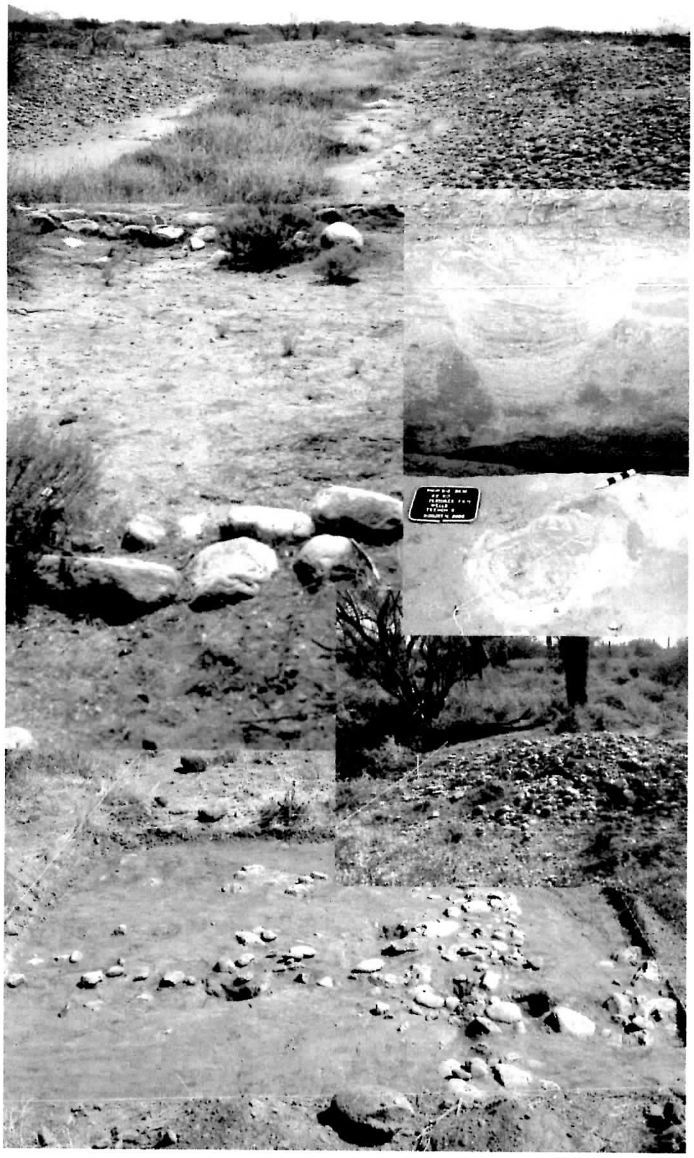
PREHISTORIC WATER UTILIZATION AND TECHNOLOGY IN ARIZONA

BACKGROUND FOR HISTORIC CONTEXTS
A COMPONENT OF THE ARIZONA HISTORIC PRESERVATION PLAN



Submitted to

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Arizona State Parks
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Phoenix, Arizona 85007

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April 2002

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CHAPTER 1

WATER – DOES A BODY GOOD, TO SAY NOTHING OF THE CROPS

Michael S. Foster

"Gimme some water, cool, cool water" – Eddie Money

Arizona, even at its best, is an arid to semiarid desert; a place that sees little annual rainfall, a place where there is little surface water, a place where prehistorically a detailed knowledge of water sources and the ability to manipulate water were critical to human survival. The prehistoric peoples of Arizona lived in and adapted to a variety of local environments (Figure 1.1), and they did this by developing a variety of water management techniques that allowed them to live in a rather hostile environment for thousands of years. Nabhan (1986a) cites Edgar Anderson (1954:26–28), who in turn notes (speaking of the Papago or Tohono O'odham), "One of the world's most remarkable agricultural civilizations…they produce a usable harvest on fewer inches of rainfall than are used anywhere else in the world." This also can be said of many of the prehistoric occupants of Arizona, and the array and combinations of technologies they used are truly fascinating.

Water sources–lakes, ponds, streams, and rivers–not only provide a resource directly consumable by humans, they also provide habitats for a variety of plants and animals used and consumed by people. Fish, amphibians, reptiles, waterfowl, a variety of terrestrial animals, and plants live in or near or congregate around sources of water, and such localities in turn draw humans to collect water as well as any plants or animals present. Water is also full of dissolved and suspended sediments and minerals that are beneficial to both humans and crops. These materials are transported via runoff, overbank flooding, or canals and are deposited on agricultural fields, replenishing nutrients in soils. Despite the positive effects of such processes, there are negative ones as well. Unproductive accumulation of sediments on floodplains, fields, and in canals, salinization of soils as a result of long-term build up of salts, and waterlogged soils are all negative consequences of too much water or long-term exposure to or use of water.

Water was transported from rivers and streams in canals and ditches to fields where crops were grown and to reservoirs that served as sources of domestic water. Rock alignments were built to direct and contain rainfall and runoff so that crops in fields could grow. Rock piles and mulch fields were built to retain water and soil moisture so plants could more readily survive the rigors of the desert in which they grew. Today, evidence for the ability of prehistoric peoples to adapt to the arid environs of Arizona and the technologies they used are scattered across the archaeological record of the state from the Colorado Plateau to the Mogollon Rim to the Sonoran Desert.

The goal of this document is to provide a framework for the investigation and preservation of cultural properties associated with prehistoric water utilization and technology in Arizona, combining and building on the subjects of two earlier documents: *Prehistoric Irrigation in Arizona* (Dart 1989) and *Prehistoric Non-Irrigated Agriculture in Arizona* (Doyel 1993a). The preparation of a new volume that addresses these issues was necessitated by the explosion of new data, as hundreds, if not thousands, of new sites and features associated with prehistoric water management have been recorded and investigated over the last decade. Not only have more sites been documented, the scope of the discussion of prehistoric water management in Arizona has expanded as well, to include a more detailed examination of the socio-

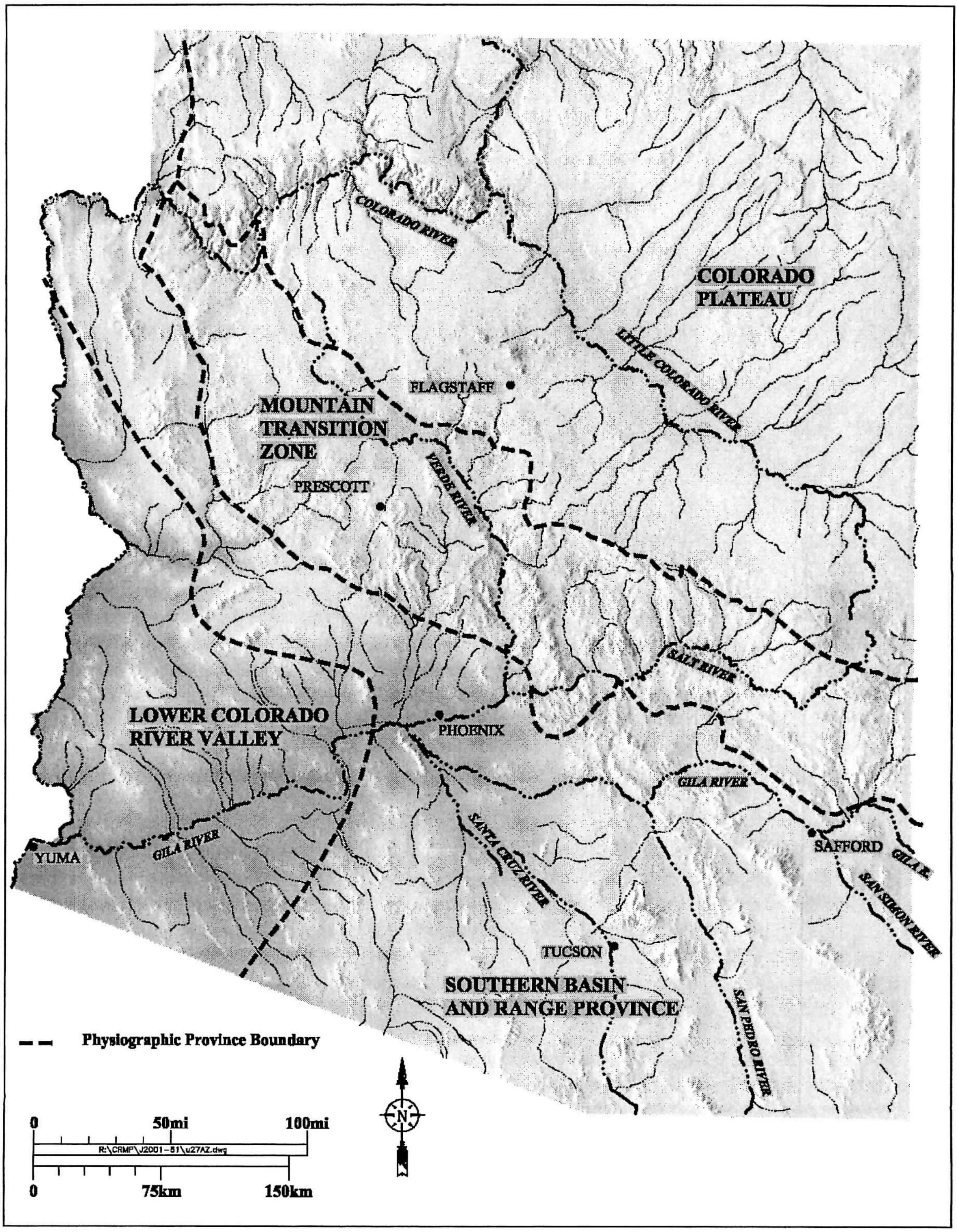

Figure 1.1. Major physiographic provinces of Arizona.

political, subsistence, and technological aspects prehistoric water management. The result has been a greater understanding of how the prehistoric occupants of Arizona managed to survive the arid environs of this region. Unfortunately, this proliferation of research has sometimes led to confusion in terminology and a less than universal application of those terms. Thus, one of the primary goals of this document is to provide a common basis from which future investigation of prehistoric water management can be pursued.

Before beginning this discussion, it should be pointed out that although there has recently been a significant increase in information on and a better understanding of the variability of water technology features, the study of prehistoric water use and technology in Arizona has a long history. Joe Ben Wheat's (1952) discussion of water sources in the Point of Pines area and Richard Woodbury's (1961a) classic study of agriculture there are two examples of early modern efforts to address the issue and classify feature types and systems. Hohokam irrigation and water storage systems have been the focus of investigations since the Hemenway Expedition in the late 1800s. These are but a few examples of early studies that built the foundation on which we work today. With the means to date such features and analyze an array of samples (e.g., pollen, sediments, aquatic fauna), our pursuit of a broader and more detailed understanding of prehistoric water utilization and technologies holds great potential for expanding our current knowledge of the prehistoric peoples of Arizona.

METHODS AND DATA SOURCES

The primary source of data for this project was the extensive body of literature on the prehistory of Arizona generated by cultural resource management and research projects across the state. Many of the volumes reviewed were from company and personal libraries. SWCA's Phoenix, Tucson, and Flagstaff offices and the Cultural Resource Management Program at the Gila River Indian Community all contributed an array of material, and Soil Systems, Inc. opened its library resources. Specific requests for information were directed to Arizona State Museum (ASM). The files and libraries at the Arizona State Historic Preservation Office (SHPO), the Bureau of Land Management, the University of Arizona, ASM, Arizona State University, the Tonto National Forest, and Northern Arizona University were reviewed by various SWCA personnel as well. The AZSite database was explored using the geographical information system interfaces developed by Dr. Stephen Savage of the SHPO. His system allows researchers to query the nearly 46,200 records in the database in ways not yet available through the World Wide Web, and he kindly assisted in the retrieval of the information we were looking for. Table 1.1 summarizes data on various water management features and associated feature and site types in the AZSite database. However, it should be noted that these data include both prehistoric and historic features. Nevertheless, the Table provides an approximation of how many water-management-related features have been recorded.

We would also like to thank individuals at the SHPO for assistance and helpful discussions regarding the content and organization of this document, specifically Compliance Specialists Jo Anne Miller and David Jacobs, and Deputy State Historic Preservation Officer Carol Griffith. Joh Czaplicki of the Bureau of Reclamation and Gene Rogge of URS Corporation also provided many helpful comments on the content of this and other documents associated with this project. A number of people cooperated in providing an array of information and materials for this project. Of particular assistance was Mark Chenault (SWCA Tucson), Dennis Gilpin (SWCA Flagstaff), Paul and Suzanne Fish (Arizona State Museum), Cory Dale Breternitz and Christine Robinson (Soil Systems, Inc.), and Barbara Macnider (Archaeological Consulting Services, Ltd.). Paul Fish was especially helpful and many of the photographs used are courtesy of Paul and Suzanne Fish and some are from the files of Richard Woodbury, which they now possess. Todd Bostwick, Phoenix City Archaeologist, provided several photographs used in the various documents associated with this project.

Table 1.1. Summary of sites with water management and related features present in the AZSite database as of November 2001.

Feature Type	**Number of Sites Recorded in AZSite**
Water/Soil control	426
Canal	188
Water-control device (unspecified)	908
Cairn (some may be agricultural features)	188
Field	49
Field house	625
Reservoir	31
Rock pile	1,948
Rock alignment – undefined	1,590
Rock feature – undefined	1,434
Trincheras	11
Burned rock midden	23
Well	110
TOTAL	7,531

PREHISTORIC WATER UTILIZATION AND TECHNOLOGIES

For the most part, the discussion of prehistoric water utilization and technologies in this volume focus on prehistoric agricultural activities, and thus, much of what is discussed is associated with the Ceramic period. The late Pleistocene hunters and Early and Middle Archaic peoples (see Mabry 1998a) probably did relatively little to manipulate water other than capture it for domestic consumption. However, this is not to say that these peoples did not have a detailed knowledge of water sources and availability. As the Late Archaic and early Formative (ceramic-producing, sedentary, agricultural) peoples became more dependent on agriculture and learned to manipulate plants, the need for knowledge of water and water control clearly increased.

Archaeological, ethnographic, and geographic literatures contain an array of terms that are used to describe and define water-management systems. Frequently, these terms are used synonymously, and in the archaeological literature there is often a great deal of ambiguity in the way they are used. One investigator's terrace may be another's check dam. One of the more comprehensive and cogent discussions of prehistoric water management technology is that of Rankin and Katzer (1989). Although focused on issues relevant to Hohokam archaeology in the Waddell Project area of west-central Arizona, their discussion is applicable to the topics covered in this document and serves as a useful introduction. Thus, with the permission of Archaeological Consulting Services, Ltd., we reproduce, with very minor editorial revision, Rankin and Katzer's classification of agricultural methods and terminology here (1989:981–986):

The literature of archaeology and geography contains a plethora of terms used to define agricultural systems. Some terms, such as runoff and rainwater harvesting (Bruins et al. 1986), are used synonymously. Ambiguous terms, such as floodwater farming, have become synonymous with ak-chin systems and with systems that utilize overflow from permanent rivers. Incorrect usage of terms, such as dry farming and ak-chin, are prevalent in the literature. Many of these terms describe agricultural systems for areas outside the Hohokam culture area and are therefore not directly applicable to the Sonoran Desert. Additionally, terms which originally described particular agricultural systems in the Sonoran Desert have been applied outside this area to agricultural systems that do not fit the definition, either by virtue of geomorphic setting or source of water. Problems of usage have resulted from the lack of understanding by archaeologists of the geomorphological and hydrological settings of these systems. These environmental factors, along with agricultural features, are critical for determining the type of agricultural system observed. The Waddell Project employed a geomorphologist in an interdisciplinary effort which had as it goal an understanding of the environmental variables associated with site locations and an integrated understanding of the agricultural systems.

A review of agricultural systems terminology reveals that each system exploits local water sources and particular geomorphic surfaces and that the systems are on a continuum based on various attributes (Nabhan 1979). Arbitrary distinctions that are based on dimensions of variability, which are closely interrelated, can be made among these systems. Attributes or dimensions of variability that are considered in the following classificatory scheme include water source, water quantity, water permanence, geomorphic setting (for both the field setting and the water source area), and water application technique. Water source includes rainfall, underground seepage and other subsurface moisture, runoff, floodwater, ephemeral streams and rivers, and perennial streams and rivers. Water permanence refers to whether the water source is perennial, flows year-round, or is intermittent with peak flows associated with precipitation or snowmelt events. The geomorphic setting of the water source is also considered to be of importance in making distinctions between types of systems. Canal irrigation from a perennial water source is distinguished from canal irrigation from an ephemeral stream or river that has peak flows associated with floodwaters. Runoff generated on slopes without being channeled into a watercourse (wash or tributary channel) is distinct from runoff that is channeled into a wash. Water quantity is related to the periodicity and intensity of precipitation, available water associated with peak flows from floodwaters, and available water from permanent water sources. The geomorphic setting of the particular field area is critical in making distinctions between agricultural systems. Field areas located in swales and floodplains are quite distinct from field areas located on terraces, slopes, and alluvial fans. Mistaken identification of the geomorphic setting of the field area can lead to erroneous classification of the type of agricultural systems represented. Finally, water application techniques, such as canals, diversion of floodwaters by simple brush weirs without the use of canals, and rock alignments, are also integral in developing a classificatory scheme of agricultural systems. Many agricultural systems actually utilize more than one source of water. In describing a dual source system it may be best to state the primary water source first along with the secondary water source.

The phrase conservation systems (Vivian 1974) has been used to refer to two very distinct types of agricultural systems in the arid Southwest: dry farming and runoff agricultural systems. Dry farming systems are only practiced in areas where there is ample rainfall. Dry farming is cropping using only direct rainfall on the field surface without any attempt to use runoff or provide additional water by irrigation (Lawton and Wilke 1979). These agricultural systems are frequently planted but not harvested due to the localized nature of rainfall. Various researchers have applied this term in referring to agricultural fields with rock piles in the Sonoran Desert (Crown 1984a, 1984b; Doelle 1976; Masse 1979). However, these "dry farming systems" are discussed in terms of conserving runoff and, therefore, application of the term dry farming to these systems is incorrect. This problem appears to stem from the definition of the term conservation system (Dart 1983a; Vivian 1974), which refers both to direct use of rainfall (dry farming) and use of runoff (runoff systems). Research by Nabhan (1979) indicates that true dry farming, that is, of annual crops watered by direct rainfall, is not possible in the Sonoran Desert. Localities suitable for true dry farming comprise most of the mountainous transition zone in Arizona, including the Point of Pines region, and much of eastern New Mexico. Marginal dry farming areas encompass much of the Colorado Plateau in Arizona, including Hopi agricultural fields, and the ecotone between the Sonoran Desert and plateau country. Use of the term dry farming should be restricted to those systems in which direct rainfall alone is used to water crops.

The delineation of runoff systems is more complex due to the number of definitions of this term. According to Lawton and Wilke (1979:4) runoff systems are fields where crops receive water as runoff from adjacent unprepared slopes. These systems are characterized by small fields that are optimally located in natural catchment basins to receive maximum available runoff. Additionally, these fields are frequently enclosed by walls of rock alignments. Gilbertson (1986) also noted that runoff systems concentrate surface runoff by use of a wall technology or alignments and terraces. However, he adds that runoff from the contributing catchment slope was enhanced by the clearance of obstacles, in this case rocks. These systems are characterized by the presence of extensive areas of rock piles, which are sometimes associated with conduits (Evenari et al. 1982).

The term runoff agricultural systems is herein defined as rainwater runoff generated on unprepared or prepared slopes of terraces and alluvial fans, also referred to as bajadas and used for agricultural purposes. Climate and geomorphologic factors affect the suitability of regions for runoff agricultural systems and the systems themselves (Bruins et al. 1986). First, the geomorphic surface must readily generate sufficient runoff. Secondly, there must be differences in elevation so that the runoff can flow and be concentrated in lower areas, which may require special preparation. Finally, soils in the runoff-receiving areas must be sufficiently deep and of suitable texture to retain runoff for agriculture (Bruins et al. 1986). As data are amassed from a wide variety of settings in the Southwest, it should be possible to further subdivide runoff agricultural systems into a number of categories based on geomorphic surface and association or lack of preparation of these landforms.

Lawton and Wilke (1979), however, have made a distinction and referred to water collection from prepared slopes as water harvesting systems. The term water harvesting systems has been used in a hydrological sense and the type of water being harvested, for example rainwater, has not been specified. Additionally, none of these terms state for what use the water is being harvested. The phrase rainwater harvesting as used by Boers and Ben-Asher (1982) is specific regarding the water source but again is not specific regarding the purpose. Rainwater harvesting has also been used synonymously with runoff systems to include all types of agricultural fields which are based upon rainwater harvesting, whether it is by means of runoff from unprepared slopes, prepared catchments, or ephemeral streams (Bruins et al. 1986). Ephemeral streams or wadis in the Old World are not synonymous with arroyos in the Southwest, although the terms have been used interchangeably. These two types of ephemeral streams have different morphological and hydrological characteristics. Nabhan (1979) has included surface runoff harvested on upland slopes and bajadas that are not channeled into a watercourse under the term floodwater systems. However, surface runoff cannot be correctly classified as floodwater, therefore, these systems belong more appropriately in runoff systems. Finally, runoff systems have been incorrectly included under the term conservation systems (Vivian 1974), which also include dry farming systems, and should be maintained as a separate category of agricultural system.

Diversion systems, in a broad sense, refer to agricultural systems in which water is collected in one area and used in another location. A number of distinct agricultural systems can be delineated under this generalized definition of diversion systems. Vivian (1974) restricted use of this term to those systems in which water was transported via ditch or canal, i.e., canal irrigation systems. Yuman use of brush weirs to divert water into swales (Castetter and Bell 1951; Spier 1933) is another type of diversion system, as is Tohono O'odham ak-chin farming that also requires the use of brush weirs to divert floodwater from washes onto alluvial fans (Nabhan 1986a, 1986b). Regardless of which definition is used, agricultural fields in diversion systems are large in comparison with dry farming systems and runoff agricultural systems. Additionally, the unit yield of water per hectare is lower than in runoff agricultural systems (Evenari et al. 1982).

The term floodwater farming (Bryan 1929) has caused a great deal of confusion in the literature. First, the term does not make a distinction between runoff agricultural systems and floodwater systems and, in fact, considers these different water sources to be synonymous, which they are not. Floodwater is concentrated in channels of ephemeral streams, large streams, and rivers from large natural watersheds. Finally, floodwater fields are situated in a variety of geomorphic settings, including alluvial fans associated with ephemeral streams (washes) and floodplains of larger streams and rivers. Floodwater farming in this report refers to peak flows associated with snowmelt or flash floods associated with rainfall precipitation events in ephemeral streams and rivers. Although Nabhan (1979) has included runoff systems within the category of floodwater farming, he has suggested that floodwater farming can be divided into specific categories that are defined on the basis of geomorphic setting of the field area and water application techniques. The terms suggested by Nabhan and Masse (1986), with minor modifications, will be used in this report because they more appropriately define agricultural systems identified along various types of watercourses and within various geomorphic settings in the Sonoran Desert. Also, although some of these systems divert water into field areas from watercourses, they do not employ canal technology. This approach has the flexibility of adding categories as agricultural fields in different geomorphic and hydrologic settings are identified.

Floodplain inundation agriculture refers to agricultural fields that are planted in rich soils deposited on the floodplains of perennial streams and rivers (Nabhan and Masse 1986) and on the deltas of rivers (Lawton and Wilke 1979). These agricultural fields can be located on a number of geomorphic surfaces such as lagoons, swales, and former sloughs on the floodplain. When describing floodplain inundation agricultural systems it is important to note the specific geomorphic surface in which the field is located. These field systems utilize the overflows associated with peak flows in rivers that inundate the floodplain. Farming along the Colorado River was possible only by inundation.

Ethnographically, the Pima and Yumans along the lower Gila, and the Mohave, Yumans, and Cocopah along the lower Colorado cleared garden plots and agricultural fields in former sloughs and swales along these rivers to take advantage of peak flows of the rivers in the late spring and early summer (Castetter and Bell 1951). Diversion of these flows was sometimes necessary along the lower Colorado and was accomplished by the use of brush and log weirs which extended into the river channel. Crops were planted after the retreat of the overflows from the floodplain and swales and matured without additional water.

The term ak-chin (Nabhan 1986a, 1986b; Nabhan and Masse 1986) has been greatly misused in the archaeological literature (Rodgers 1985). Excellent overviews of this term by Nabhan (1982, 1986a, 1986b) have clarified some of the problems regarding its meaning and application. Ak-chin, a Tohono O'odham word, was first used by McGee in 1897 to refer to agricultural fields that were located on the arroyo deltas or the ak-chin mouth of a wash where floodwaters spread out (Nabhan 1986b). The idea that ak-chin farming was synonymous with an arroyo mouth is prevalent in the literature (Bryan 1929) and has been a key factor in the misuse of this term. Nabhan (1986b) has pointed out that arroyos have been used to refer to both unincised and incised ephemeral streams and that the success of Tohono O'odham cultivation at these so-called arroyo mouths became synonymous with ak-chin farming. However, among the Tohono O'odham, ak-chin does not refer to fields but is restricted to refer to villages or specific locations along ephemeral watercourses at a specific time (Nabhan 1986b).

Ak-chin refers to a specific geomorphic and hydraulic situation that changes location over time, and field locations are moved or abandoned in accordance with these changes. The ak-chin is the specific area on the alluvial fan where the floodwaters spread out. This area is located between the zone of concentration where wash channels are joining, and the zone of distribution where channels of a wash are diverging (Nabhan 1986b). Use of the term ak-chin farming to refer to agricultural fields situated within swales on the floodplain of the central reaches of New River (Doyel 1985; Rodgers 1985) is incorrect. Some of these agricultural fields (Rodgers 1985) are floodplain inundation agricultural systems and others are floodwater canal irrigation systems. Use of an "emic" category such as ak-chin, should be restricted to specific O'odham ethnographic or ethnohistoric context and has no place in an etic classificatory scheme. Agricultural fields located where floodwaters from arroyos or intermittent washes spread out onto alluvial fans are referred to in this report as alluvial fan floodwater systems.

Nabhan (1979) has indicated that agricultural fields are also located in the bottoms of ephemeral watercourses or broad arroyos and the water is controlled by brush weirs or dams. These situations are referred to as arroyo bottom agricultural systems. Agricultural systems in which water from arroyos is diverted by weirs onto terraces or storage basins are referred to as terrace or storage basin inundation agricultural systems, depending on the specific geomorphic surface.

Irrigation systems refer to agricultural practices in arid regions that use the artificial application of water in order to grow crops (Lawton and Wilke 1979). A canal irrigation system "involves the transport of water from a source by means of gravity flow through artificially constructed canals to facilitate cultivation["] (Doolittle 1988[a]:1–18). These systems are referred to as canal irrigation agricultural systems, indicating that the water is used solely for agricultural purposes. Some canal irrigation systems supply water for domestic purposes. Canal irrigation agricultural systems are generally composed of three

> components. The first component is the headwater feature (headgate), usually a brush and pole weir which is placed at a diagonal angle in the channel of the watercourse and diverts flow from the channel into the canal. Canals carry the water from the source to field areas where field features, such as rock and brush alignments, spread the water. Since the sources of water can vary from perennial rivers that are constantly flowing, to ephemeral large streams and rivers, a distinction was made based on the source of the water supply. Doolittle (1988[a]) has suggested the use of the term permanent irrigation to refer to systems that utilize a perennial source of water but do not necessarily practice irrigation on a year-round basis. Floodwater irrigation (Doolittle 1988[a]), on other the hand, refers to canal irrigation from ephemeral large streams and rivers that have peak flows associated with snowmelt or rainfall precipitation events [Rankin and Katzer 1989:981–986].

The classificatory scheme outlined by Rankin and Katzer (1989) is generally employed, with some variation, in this document. Others (e.g., Fish, Fish, and Madsen 1992 ed. 1992; Glassow 1980; Lawton and Wilke 1979; Masse 1979, 1991a) have provided useful definitions of different property types and discussions of prehistoric water management technologies that are also extensively employed or referred to here. Uses of water, beyond those described above, are discussed as well. Humans used tinajas (natural tanks or reservoirs), seeps, and wells as sources of water. Rivers supplied food and indirectly served as transportation, communication, and commercial corridors, as the valleys and drainages through which they pass often provided easy access to neighboring areas. To say the least, prehistoric utilization of water was varied and innovative.

WHY STUDY PREHISTORIC WATER UTILIZATION AND TECHNOLOGY

Why study prehistoric water usage and technology, why are such sites and features worth investigating and preserving, why are they important? There are two obvious answers to these questions. First, because prehistoric water technologies and their physical manifestations are part of the record of humankind, and simply documenting and studying human history is itself important. Secondly, in a place like Arizona, an arid desert, without water-management and technology there would likely be very little archaeological record. Beyond this, however, the use and management of water has played a critical role in human social and economic development across the face of the earth (e.g., Adams 1966; Boserup 1965; Downing and Gibson 1974; Hunt and Hunt 1974). Manipulation and control of water allowed areas not previously occupied by humans to be settled, allowed people to become sedentary, and allowed populations to grow in size and complexity. Water control contributed significantly to the rise of some of the more elaborate and complex societies in the ancient world, while in the New World extensive irrigation systems such as those in central and southern Arizona produced only a middle range society that appears to have lacked significant social stratification or a far-ranging economic system. The significance and meaning of such a wide disparity between cultures and in cultural evolution merits intensive study and discussion, both at a local level and worldwide. Clearly the study of prehistoric water utilization and technology in Arizona offers a unique opportunity to expand our knowledge of human adaptation to and utilization of a variety of environments over a long period of time.

GOALS

This document has several major goals beyond describing and discussing prehistoric water utilization and technology in Arizona. One of the consequences of this effort, it is hoped, is that there will be a single primary resource on these technologies and associated property types, and that this will result in more consistent and appropriate use of terminology. Inconsistencies sometimes exist within a single document, as well as from one investigator to another. Some of this ambiguity rises from investigators working in different culture areas applying the same terms to features that functioned differently. Whatever the case may be, and despite the attempts of some investigators (e.g., Masse 1979, 1991a; Vivian 1974), there is a significant need for the archaeological community of Arizona to standardize the terminology used, if not across the state, at least within culture areas.

The second goal is to provide guidelines for evaluating the integrity and significance of property types for the National Register of Historic Places (NRHP). There clearly is a tendency for archaeologists to recommend the property types discussed in this document as potentially eligible or eligible for the NRHP simply because they exist. Furthermore, after reviewing numerous cultural resource management reports for this document, it is clear that there is often little real assessment of the integrity of these features and whether further investigation of individual or groups of features, might actually yield important information that will contribute to our understanding of past human culture. Additionally, when considering NRHP eligibility, there is often an overemphasis on the feature or field system and no consideration of where that feature fits within a given cultural landscape. After nearly 30 years of study, we have a good understanding of what these features were used for and what was grown on or around them. This certainly is not to say that there is no more that could be learned from the intensive investigation of such features, but perhaps there are many cases, especially where features are eroded and deflated (lack integrity), where simply documenting the presence of these features and systems and understanding them in terms of the local cultural landscape is sufficient. Critical assessment of the NRHP eligibility of such features, and of archaeological remains in general, is extremely important as a mechanism to promote the protection and research potential of sites.

The third primary goal of this document is to provide background information for use in the development of historic contexts for the study of prehistoric water utilization and technology in Arizona. Historic contexts organize information around a theme, place, and time, and include information about how property types within particular stages of cultural development occurred at various times and places (see National Park Service 1986:7).

The document is also concerned with the management of cultural resources related to prehistoric water utilization and technology, research issues, and data gaps. Native American concerns, and the educational and recreational uses of such properties are also addressed.

DOCUMENT ORGANIZATION

This document is divided into seven chapters. The first chapter introduces the goals of the document. Chapter 2 discusses humans and water and summarizes the prehistory of Arizona. Chapter 3 discusses non-irrigated agricultural water management technologies and property types (rock piles, check dam, terracing, etc.), Chapter 4 discusses floodwater and other water utilization and management technologies, and Chapter 5 focuses on prehistoric canal technology and irrigation. National Register of Historic Places evaluation of prehistoric water management property types is discussed in Chapter 6. Chapter 7 concludes the volume with discussions of the management of prehistoric water usage and technology properties, research issues, Native American concerns, and the educational and recreational values of these properties. A partially annotated bibliography contains not only the references cited in this document, but a series of references related to the topics discussed here.

CHAPTER 2

WATER AND HUMANS IN PREHISTORIC ARIZONA

Michael S. Foster and M. Kyle Woodson

"Man's inescapable attachment to watering places
has been an important factor in determining his residence." – Emil Haury (1976:152)

WATER–FRIEND AND FOE

Humans, like all other living creatures, require water in order to survive. However, for humans, being the cultural creatures we are, water is more than a simple life-sustaining fluid. We exploit, capture, and use water in a bewildering array of ways. Very early in human history we probably learned to store and transport water, and we eventually learned how to channel it and move it from its point of origin to where it was needed. We learned to play in it and use it as a means of transportation, and many of us have died fighting over it. Water is and has been a coveted and essential resource for the survival of our species. Its role as a prime mover in the formation of social complexity in both the Old and New Worlds has been debated and discussed in detail in the anthropological literature (e.g., Adams 1966; Downing and Gibson 1974; Wittfogel 1957). Numerous examples exist of people living in similar environments in both the Old World and the New, separated by many thousands of miles and many hundreds of years, developing and using similar techniques and features for the manipulation and control of water (e.g., Neely 1974; Vivian 1974). The Old World has canal irrigation systems, rock piles, and terracing, as does the New World. Old World peoples learned to manipulate water, allowing them to grow crops, live in settled villages, and, in some areas, develop economically and socially complex societies. Some of those societies became highly stratified states and the world's first civilizations. There are many parallels in the New World. Although the prehistoric societies of Arizona did not become highly stratified or state-level societies, their use and manipulation of water and the impact of water control did, nevertheless, have significant and far-reaching social and economic implications within groups and at regional levels. There is no place on earth where the relationship between humans and water is not complex, but not all societies that manage and manipulate water are complex.

Undoubtedly, the earliest occupants of Arizona, the Paleoindian hunters and Early and Middle Archaic hunter-gatherers, had detailed knowledge of water sources and how to obtain water for their daily survival. The presence or absence of water certainly dictated movement across the landscape as much as did the availability of the resources being sought. These early people lived in small kinship-based bands that lacked highly structured leadership and whose membership likely had equal access to the resources being captured.

The origins and role of agriculture in Southwest societies are highly controversial and debatable issues (e.g., Hard and Roney 1998; Huckell 1995, 1996a; Mabry 1998a; Matson 1991; Wills 1988, 1990). Many details, such as dates of origin, impacts on prehistoric groups, and level of dependency, are not agreed upon by all archaeologists. It is widely accepted that maize was being cultivated in Arizona by circa 2900–2500 years ago (Huckell 1996a; Mabry 1998a). Recent dates suggest that initial cultivation could have started even earlier, as far back as 4050 years ago (Gregory 1999; Mabry 1998a). Other cultivated plants, including squash, cotton, and beans, were being widely cultivated by 2900–2500 B.P. (Mabry 1998a). Additionally, cultivation is often accompanied by methods for storing harvested crops, seeds between seasons, and water. Evidence for prehistoric water storage dates back as early as 6000 years ago (Crown 1987a).

Because an in-depth discussion of agriculture's origins in Arizona is beyond the scope of this volume, our focus is evidence for when various agricultural strategies were widely in place. Although we do not know exactly when it began, there is evidence demonstrating that agriculture was being practiced during the late Archaic (Geib and Huckell 1994; Wills and Huckell 1994). Since there is a lack of agriculturally related features from this early period, the evidence comes from pollen remains of cultigens (especially maize) that would not be able to grow without human assistance. An interesting recent study documents a direct correlation between mano size and dependency on maize within various Hohokam groups. It seems that as the level of dependency rose, so did the size of grinding surfaces on manos (Diehl 1995). The degree to which these earliest farmers relied on cultivated crops was probably low, as they maintained a rather mobile lifestyle. A lack of agricultural features prior to the first century A.D. further supports the notion that although agriculture was being practiced during the Late Archaic, Early Agricultural, and early Ceramic periods, it was incipient in nature and not the main source of subsistence. It is difficult to date these sequences because of the scarcity of artifacts and features (Fish et al. 1992a). Around A.D. 400, towards the end of the early ceramic period, more sedentary type hamlets and agricultural features began to appear across Arizona (Doyel 1991).

As agriculture became more widespread, there were major variations between regions regarding the level of intensity with which it was practiced, the size of the role it played within a group's overall subsistence, and what agricultural strategies were utilized. These variations were due to a multiplicity of factors, including environment, topography, water sources, population, and social structure, and led to a high degree of regional differences when studying prehistoric water usage throughout Arizona (Glassow 1980; Hard et al. 1996; Haury 1976; Vivian 1974). Moreover, archaeologists have not yet given all areas the same amount of attention, making such regional comparisons difficult.

Agriculture and sedentism impacted the social, political, and economic organization of prehistoric Arizonans. In central, southern, eastern, and northern Arizona, the early band-level societies reorganized to accommodate village life and higher population densities. The increased dependency on agriculture and higher population densities brought about the need to manipulate and maximize water supplies, perennial, ephemeral, and rainfall as populations grew and aggregated, and there was a greater demand for domestic water and a greater need for water for increased crop production. In general, it appears that most of the water-management techniques discussed in this volume were a response to increased population densities and agricultural intensification rather than a factor in bringing about these changes. Certainly, these techniques allowed high population densities and aggregation to be maintained for sustained periods of time. One exception may well be in the Hohokam culture area, where early canal irrigation not only did help sustain higher population densities as the use of agriculture increased, but its success appears to have contributed to the formation of larger settlements. Nevertheless, the issue of water management and increase in population densities and social complexity remains, to some extent, a chicken-and-egg dilemma: which came first?

The most obvious and intensive interaction between humans and water in prehistoric Arizona is best seen in the Hohokam region of central and southern Arizona. The transition from hunting and gathering occurred during the Early Agricultural period or around 2000 B.C.–A.D. 1/150. Between A.D. 1/150 and 750, the Early Formative and Pioneer periods, agriculture contributed more significantly to the subsistence base, and basic water management technologies appeared. By the end of this period a village-farming lifeway was well established. During the following Colonial and Sedentary periods, A.D. 750 to 1150, there was a tremendous elaboration of Hohokam society that included greater dependence on and use of agriculture and the amplification and expansion of water-management technology. During the Pioneer period canal systems were generally localized and likely independent (Neitzel 1991). Many large villages were formed, and geographically, artistically, economically, and sociopolitically, the Hohokam reached the apex of their cultural development (Doyel 1991). It is during this period of time that extensive irrigation canal systems were built in the Salt and Gila River valleys. An important question regarding the role of the canal systems is the level of sociopolitical organization that it took to construct and maintain them and what were the sociopolitical mechanisms that were in place to allocate water. Some have argued that the Hohokam developed into a highly complex society in order to contend with the issues of canal water management, while others have argued that such systems were built and maintained through cooperative efforts under less institutionalized leadership.

During the subsequent Classic period, canal irrigation continued to play a significant role in the sociopolitical organization and subsistence of the Hohokam. Platform mounds appear at large villages and both large villages and outlying smaller villages expanded or were established along canal systems. These are thought to have functioned as communities (e.g., Cable and Mitchell 1991; Fish and Fish 1991; Gregory and Nials 1985).

Clearly, the use and management of water over time became more complex as the prehistoric inhabitants of Arizona became more dependent upon and expanded the use of the cultigens they had adopted. Population densities increased, populations aggregated, and social and economic complexity increased in many areas until the late A.D. 1300s and early to mid A.D. 1400s when, environmental factors across the Southwest restricted the use of agriculture and forced the abandonment of many areas (e.g., Cordell 1997; Fish, Fish, and Gumerman 1994). Agriculture is often seen as an adaptation that stabilized the food supply and allowed populations to settle and grow. Adoption of agriculture was, however, not without its negative consequences. Skeletal evidence from across the Southwest indicates that disease related to poor nutrition increased with greater and greater dependence on cultigens, and as agricultural systems began to collapse, populations came under increasing physical and social stress (Martin 1994). The stature of the people even decreased (e.g., Nickens 1976). By the late A.D. 1300s and early 1400s populations in many areas were suffering significantly as the irrigation and water-management systems they depended upon failed. One of the most recent and well documented examples of the impact of poor nutrition associated with the collapse of irrigation farming comes from the Hohokam site of Pueblo Grande, where the Late Classic period people suffered greatly (Van Gerven and Sheridan 1994). The collapse of the Hohokam irrigation systems during the Late Classic played a significant, if not causal role, in the decline and collapse of the Hohokam (Gregory 1991; Nials, Gregory, and Graybill 1989).

Additionally, human contamination of water sources (ditches, canals, wells, reservoirs) that may have provided domestic water was almost certainly a problem (e.g., Fink 1991). Fink notes that such water, despite its origin and assumed purity, contains sufficient nutrients to support bacterial growth. Human, and probably animal, excrement deposited directly in water sources inadvertently or deliberately or washed in by rainfall runoff would likely contaminate water supplies. It is also possible that individuals with open wounds might have exposed infected sores to water supplies thus disseminating bacteria in the water. Decomposing trash may also have been inadvertently contaminated water supplies. This is not to say that the prehistoric inhabitants of Arizona were unsanitary. Unfortunately, one of the consequences of human aggregation is a decrease in the level of sanitation and an increase in the exposure to infectious diseases, waterborne or otherwise.

Another aspect of prehistoric human water and land use focuses on the environment itself. Clearing lands of natural vegetation for agricultural purposes facilitated water and wind erosion, as well as altering the local vegetational landscape (e.g., Redman 1999). Concentrations of people and intensification of agricultural activities, especially maize cultivation, resulted in the depletion of soil nutrients and the use of greater and greater amounts of land for agriculture. Long-term irrigation resulted in the increased mineralization of soils and waterlogging of fields, rendering them less productive (e.g., Ackerly 1988). Flooding also impacted irrigation systems by blowing out headgates and the canals themselves (e.g., Howard and Huckleberry 1991; Nials, Gregory, and Graybill 1989). Entrenching of streams and rivers and changes in their courses also impacted the workings of irrigation systems. Canals also carried sediments that revitalized agricultural soils, but also impacted the functioning of the canal system (Howard 1990; Howard and Huckleberry 1991). Thus, in many ways, water was both friend and foe.

PREHISTORIC ARIZONA: AN OVERVIEW

Human occupation of Arizona dates back nearly 12,000 years, and perhaps more. Some of the classic Paleoindian and Archaic period sites excavated in the American Southwest occur in Arizona, and parts of Arizona, unlike neighboring New Mexico, Colorado, and Utah, were occupied by all the major Southwestern cultural traditions (Prehistoric Pueblo [Anasazi], Mogollon, and Hohokam). There were also a variety of localized cultural traditions found for the most part only within Arizona's borders including the Salado, Sinagua, and Patayan. Following the Paleoindian and Archaic periods, prehistoric Arizona can be divided into six culture areas corresponding to these six indigenous groups (Figure 2.1). Much of the archaeology that is discussed in the following chapters is associated with these Ceramic period cultural traditions of Arizona; a time of intensive agriculture that led to greater sedentism, the use of the bow and arrow, and the widespread production and use of ceramics (Bruder et al. 1989).

Paleoindian Period

The Paleoindain and Archaic periods in Arizona have recently been the subject of a detailed overview produced as a historic context for the SHPO (Mabry 1998a). Traditionally the earliest human occupation of the Southwest and Arizona is associated with the Clovis hunters of terminal Wisconsin times, 11,600 through 10,900 years ago. The Paleoindian tradition is defined by the presence of a series large projectile (spear) points that are often found in association with late Pleistocene megafauna such as the mammoth and bison. However, in southern Arizona there is evidence of pre–projectile (pre-Clovis) point complexes variously referred to as Malpais and San Dieguito I (Hayden 1967, 1976; Rogers 1929, 1958). The lithic assemblages associated with these complexes consist of large scrapers, unifaces, choppers, cleavers, denticulates, spokeshaves, and some flake tools made mostly from basalt by hard-hammer percussion. No bifacially flaked tools or projectile points are present, and none of the Malpais material appears to have given rise to any of the tool types or technologies associated with the Clovis tradition. Malpais I is suggested to date to more than 24,000 years ago, and Malpais II is suggested to date between 24,000 and 18,000 years ago (Hayden 1976, 1987). San Dieguito I materials are suggested to date between 17,000 and 9,000 to 7,000 years old (Hayden 1976). Although a pre–projectile point horizon predating the Paleoindian tradition in the Southwest is a provocative suggestion, and one that merits further systematic study, it is an idea that is not widely accepted and is not without critics.

Paleoindian sites are often open sites near streams, although one of the early levels of Ventana Cave is thought to be Paleoindian in age (Haury 1950; Reid and Whittlesey 1997). The earliest of these complexes or traditions is the Clovis, with its hallmark large, fluted spear point. Also associated with the Clovis complex is an array of other lithic implements, including prismatic blades and bifacially flaked performs, flake and blade tools, and bone and ivory implements. Clovis finds include isolated artifacts, sites that may be base camps, and kill sites with associated temporary processing camps. One of a number of Clovis sites in the upper San Pedro River valley, Murray Springs, may have had a well (Haynes 1973; Mabry 1998a). Clovis peoples are generally seen as hunters who likely supplemented their diet with wild plants.

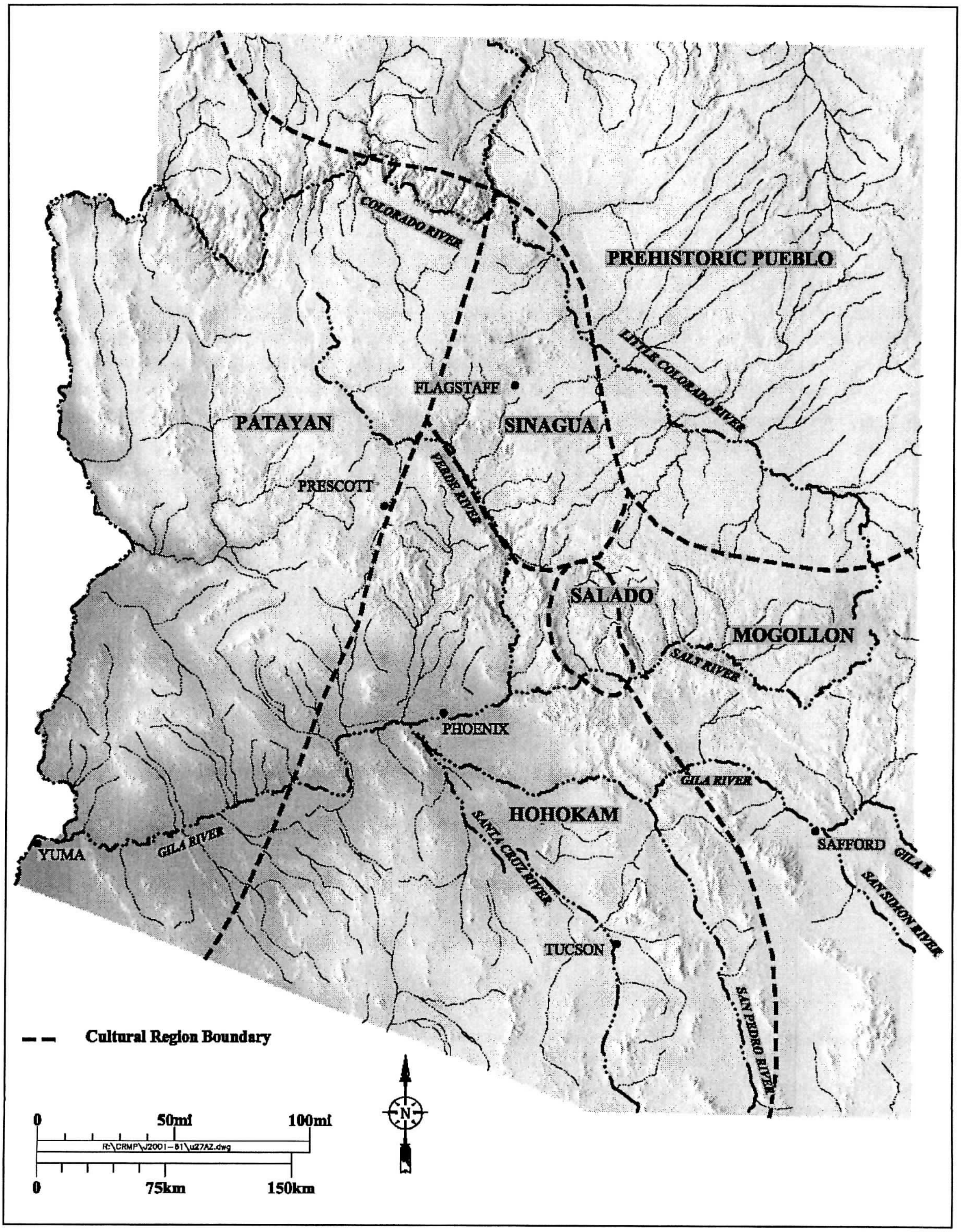

Figure 2.1. The boundaries of prehistoric cultural traditions within Arizona.

Following the Clovis complex is the Folsom complex, identified by a smaller point with a flute that extending the entire length of the blade. Folsom points are better made, by pressure flaking, than are Clovis points. The Folsom toolkit also included gravers and endscrapers, bone gaming pieces, and miniature projectile points. Folsom points and materials are most commonly found in association with bison remains. Most Folsom finds in Arizona come from the Colorado Plateau.

The Folsom complex is followed by a series of complexes. The Plainview, Agate Basin, and Cody complexes are characterized by a series of stemmed and lanceolate projectile point types and other tools. Hunting of bison continues to be a focus of these early Holocene hunters. Most of the point types (Plainview, Agate Basin, Eden, and Scottsbluff) associated with these complexes have been found on the Colorado Plateau.

The use of water during these times was likely almost entirely for domestic consumption. Streams, rivers, lakes, ponds, tinajas, and wetlands (ephemeral and perennial) provided water for Paleoindians to drink and use as necessary. There is, not surprisingly, evidence of wells having been dug. The availability of water was tied to the movements of the animals they hunted: water attracted animals; water and animals attracted humans.

Archaic Period

The time following climatic amelioration and the extinction of the previously exploited megafauna saw the emergence and flourishing of the Southwestern Archaic Tradition (8500 B.C. to around A.D. 1/150). This period in Arizona is best understood from remains in southern Arizona. The Early and Middle Archaic periods in the Prehistoric Pueblo area of north central and northeastern Arizona and the Mogollon area of the eastern mountains are poorly documented. A variety of projectile point types–Pinto, Jay, Elko, and Armijo-Gypsum style points–characterize the Archaic period in these areas. For a more detailed and far-ranging discussion of the Archaic period and early agriculture on the Colorado Plateau, the reader is referred to Matson (1991) and Mabry (1998a).

In southwestern Arizona the Archaic period is manifested in the San Dieguito Complex (ca. 10,000 to 7,500 years ago), which is characterized by leaf-shaped bifaces and projectile points, crescents, engravers, and a variety of scrapers. San Dieguito features include cleared sleeping circles, trails, rock rings, and pebble-covered earthen mounds. Ground stone is absent or rare.

In southern Arizona, the original designation of Cochise culture (Sayles 1983; Sayles and Antevs 1941) proposed for the Archaic period has been abandoned in favor of the more generic "Southwestern Archaic Tradition" (Huckell 1984a; 1995). This tradition is characterized by small, mobile residential groups that hunted medium to small game and foraged for a variety of floral resources (Huckell 1984a, 1984b). Such a subsistence-settlement pattern persisted through the Early (8500–5000 B.C.), Middle (5000–1500 B.C.), and Late (1500 B.C. to around A.D. 1/150) Archaic periods (Huckell 1984a, 1995), although there was a trend toward an increasing reliance on gathering within a seasonal round, as evidenced by the increased presence of grinding tools in the artifact assemblage.

Little is known about the Early Archaic period (Sulphur Springs–Ventana phase/stage) anywhere in southern Arizona. The first definite evidence of human occupation in the region dates to the Middle Archaic period (Huckell 1984b; Neily, Ciolek-Torrello, and Sterner 1999). The Middle Archaic period (Chiricahua phase/stage) appears to be characterized by highly mobile populations making use of diverse microenvironments, including riverine settings, stabilized dune fields, bajada settings, and mountain pediment locations (Bayham et al. 1986; Dart 1986a; Huckell 1984b; Neily, Ciolek-Torrello, and Sterner 1999; Stevens 1999). Sites are relatively small and lack dense occupational refuse, elaborate storage facilities, and structures (Neily, Ciolek-Torrello, and Sterner 1999).

A number of Middle Archaic period sites have been identified in and around the Tucson Basin (e.g., Dart 1986a; Douglas and Craig 1986; Huckell 1984b; Stevens 1999). In the Phoenix Basin, Middle Archaic period sites appear to represent short-term seasonal field camps or long-term base camps (Bayham, Morris, and Shackley 1986; Fish 1968; Halbirt and Henderson 1993; Neily 1991). Recent work on the Gila River Indian Community has documented a number of previously unknown Middle Archaic sites along Lone Butte Wash and McClellan Wash (Bubemyre, Broadbeck, and Neily 1998; Neily, Broadbeck, and Peterson 1999; Woodson and Davis 2001). Although the period is not as well understood in the Phoenix Basin, surface finds of temporally diagnostic projectile points, as well as points recovered from later Hohokam sites, attest to the widespread use of the area during the Archaic period.

The Southwestern Archaic Tradition of hunting and foraging appears to have persisted throughout southern Arizona betweem 2000/1500 B.C. and around A.D. 1/150). This time also constitutes a transition characterized by early agricultural efforts and increased sedentism. Because of differences between sites representing these two subsistence-settlement patterns, it has been suggested that sites of the hunting/foraging type be designated "Late Archaic" and more sedentary settlements be designated "Early Agricultural" (Huckell 1995; Mabry 1998a). The Early Agricultural period (ca. 2000 B.C.–A.D. 1/150) is divided into three phases: an early unnamed phase (2000–1200 B.C.; Jonathan Mabry, personal communication 2000, 2000; the San Pedro phase (1200–800 B.C.); and the Cienega phase (800 B.C.–A.D. 1/150).

At many Late Archaic period sites in southern Arizona, especially those in more xeric areas, the tradition of hunting and foraging appears to have persisted with no reliance on agriculture, although accompanied by increasing sedentism (Bayham, Morris, and Shackley 1986; Halbirt and Henderson 1993; Huckell 1984a, 1984b). The Late Archaic is represented by a number of sites throughout most of southeastern Arizona. Recent work has also demonstrated a significant Late Archaic exploitation of secondary wash environments in the middle Gila Valley (Bubemyre, Broadbeck, and Neily 1998; Neily, Broadbeck, and Peterson 1999; Woodson and Davis 2001). As in the Middle Archaic period, these Late Archaic period sites generally are manifested as small, seasonally occupied, limited-activity locales in diverse microenvironments. At issue is whether sites manifesting a "Late Archaic" foraging pattern with no evidence of agriculture served as seasonally occupied camps within a settlement system focused on the floodplain agricultural villages (e.g., Huckell 1995; Roth 1992, 1995) or represented a distinct but contemporaneous subsistence-settlement system.

Beginning around 2000 B.C., groups occupying upland and primary or secondary stream course locations in southern Arizona adopted maize horticulture and developed a semi-sedentary subsistence-settlement pattern (Huckell 1995; Mabry 1998a; Matson 1991). Large, seasonally occupied villages, some with communal structures, were common in some areas by 800 B.C. (Mabry 1998a; Roth 1993). Pit houses were generally oval or round, and the first house clusters and house groups appeared (e.g., Huckell 1995; Mabry 1998a). The earliest ceramic containers in the American Southwest have been recovered from sites of this period (Heidke 1999). The subsistence base for these villages centered on floodplain maize agriculture, to a limited extent riparian resources, and continued exploitation of upland resources (as evidenced by seasonally occupied camps; Dart 1986a; Douglas and Craig 1986; Huckell 1995; Roth 1995). In addition, the earliest canals known in the Southwest have been discovered near these floodplain villages (Mabry 2000). The most important Early Agricultural period discoveries involve sites along Cienega Creek (Huckell 1995) and along the Santa Cruz River (Mabry 1998a), where early maize has now been dated between 2000 and 1200 B.C.

Preceramic, semi-sedentary horticultural settlements have not been identified in the middle Gila Valley. It is likely that if Early Agricultural period settlements were present in the area, they might have been situated along Holocene terraces that had potential for floodwater agriculture and, consequently, might be deeply buried in alluvium. Other settlements are expected in high-water-table areas along tributary drainages away from the floodplain. Cienegas, which would have favored early agricultural efforts, have been documented in historical times in certain parts of the middle Gila Valley (Rea 1997).

In other parts of southeastern Arizona evidence suggests that early horticulturists were establishing settlements in higher-elevation (above roughly 2,000 feet) riverine environments. Recent excavations by Archaeological Consulting Services, Ltd., in the lower reaches of the upper Gila Valley at the Kearny site (AZ V:13:201[ASM]) revealed approximately 70 Early Agricultural period (Cienega phase) pit structures with extramural pits beneath a Sedentary period Hohokam occupation (Clark 2000). In the Safford Basin, McEuen Cave has produced evidence of early maize (Huckell et al. 1999), and recent excavations by Desert Archaeology, Inc. at AZ CC:2:289(ASM) near Safford revealed a probable Early Agricultural component (Clark 2002). No Early Agricultural period sites have yet been discovered in the Lower San Pedro Valley.

Prehistoric Pueblo

Northeastern and north-central Arizona were occupied by a cultural tradition commonly referred to in the archaeological literature as the Anasazi and in this document as the Prehistoric Pueblo. The Prehistoric Pueblo tradition is often broken into two groups, the Eastern and Western, each of which has several branches. In Arizona the Western Prehistoric Pueblo tradition is also referred to as Hisatsinom, the Hopi word meaning "our ancestors."

The most recent summaries of the Western Prehistoric Pueblo are those of Gumerman and Dean (1989) and Reid and Whittlesey (1997). It should be noted that Gumerman and Dean recognize four branches in the Western Prehistoric Pueblo area, the Kayenta, Virgin, Tusayan, and Winslow. They see the Virgin branch as an attenuated version of the Kayenta branch, the Tusayan branch is distinguished by minor technological differences in ceramics, and the Winslow branch is limited in time and has a distinctive ceramic and architectural tradition that separates it from the Kayenta tradition. This discussion draws heavily from these two sources to summarize general trends in the culture history of the area and follows the chronological scheme suggested by Gumerman and Dean.

Basketmaker II (560 B.C. – A.D. 700)

Basketmaker remains in northern Arizona are well documented, and this time equates in general with the Late Archaic or Early Agricultural period of central and southern Arizona. Until recently it was argued (and is still by some) that Basketmakers were derived from local Archaic period populations. More recently, it has been suggested that the appearance of Baskemakers on the Colorado Plateau is the result of the spread of San Pedro Cochise (Southwester Archaic Tradition) people from southern Arizona into the area (Matson 1991). Basketmaker sites occur mainly in caves or rock shelters, protected places that formed the ideal location for a base camp to which hunting and gathering or part-time farming people could return to regularly. Occupations likely were often tied to seasonal rounds. Open sites have been excavated, and circular house remains with slab-lined entryways have been exposed. The material culture of these groups is marked by a variety of well-made baskets, textiles, twined fur robes, cordage, use of human hair, and personal adornment made from shell and turquoise. Based on the differential distribution of these exotic items in burials, it appears that some people were able to accumulate greater wealth than others.

Basketmaker II subsistence was a mix of hunting, gathering, and horticulture, with both, corn, and squash being grown. Additionally, evidence indicates dogs were domesticated. With the introduction of cultigens, a stable and permanent occupation of the Colorado Plateau became possible. Agricultural activities were probably restricted to floodwater and dry-farming techniques (Matson 1991).

Basketmaker III (A.D. 550 –825)

Basketmaker III sites are also abundant throughout the Western Prehistoric Pueblo area. Rock shelters continued to be used as campsites, but were eventually abandoned in favor of pit houses. Pit house villages are located in lowland settings along the edges of floodplains suitable for farming. The villages range in size from several to many pit houses built following the same pattern. Some had antechambers and double ventilators; slab-lined storage pits were located behind the pit houses.

Village size and configuration suggest a higher level of social organization during this time. Individual residential units–pit houses and their associated extramural features–were integrated into larger villages. One site, the Juniper Cover site, has a great kiva that may have served as a point of ceremonial activity for a multi-settlement community.

The Basketmaker III artifact assemblage clearly reflects increased sedentism. Pottery (a plain grayware) is introduced, stone axes are common, the bow and arrow replaces the atlatl (a spear-throwing device of the Archaic period), and well-made projectile points are produced. An abundance of marine shell in Basketmaker III sites indicates continued involvement in a long-distance exchange network similar to that seen in earlier times.

Overall, there was an increased emphasis on farming during Basketmaker III times. Floodwater, dry-farming, and groundwater farming techniques appear to have been the primary methods of watering crops. Numerous limited activity sites occur away from the habitation sites, indicating that hunting and gathering continued to play an important, but different, role in Basketmaker III subsistence activities. The uplands were abandoned in favor of the lowlands, where rich soils and water for agriculture were more plentiful.

Pueblo I (A.D. 825-1000)

Pueblo I times are defined by the widespread appearance of black-on-white pottery and the use of masonry pueblos. Pit houses continue in use and are similar to Basketmaker III pit houses except they no longer have antechambers. Exterior storage facilities are more varied and include circular slab-lined cists or rectangular jacal, slab-lined, or masonry rooms. Extramural work areas have also been identified. Nevertheless, understanding of Pueblo I site structure has been problematic. No great kivas or other overtly ceremonial structures have been identified in the Western Prehistoric Pueblo area, and it is thus not evident that Pueblo I villages were integrated into larger communities. Despite the lack of ceremonial features, Pueblo I times represent a continuation and elaboration of the cultural trends established in Basketmaker III times.

Pueblo I material culture is very similar to that of the preceding Basketmaker III period but more elaborate. In addition to decorated ceramics, new styles of projectile points appear. The abundance of projectile points indicates a continued reliance on big-game hunting. One class of item that disappears is the limestone chunks so common in Basketmaker III sites, apparently signaling the end of boiling with stones as a food preparation technique.

By Pueblo I times subsistence is firmly based on agriculture. Hunting and gathering remain important but contribute less to the overall diet. In most areas settlements are still concentrated along lowland drainages, but larger numbers of permanent settlements have been established adjacent to major upland drainages, especially on Black Mesa. Gumerman and Dean (1989:116) note that aggregation of populations into large communities on floodplains of major drainages is a departure from the earlier Basketmaker III avoidance of settlement on floodplains. They suggest that this change was the result of increased dependence on farming combined with the restriction of arable land and the stabilization of alluvial surfaces caused by the lowering of groundwater levels and arroyo cutting. Thus, the use of groundwater as a farming technique would have diminished and disappeared. However, it is during late Pueblo I times that there is the first evidence for the use of water management devices such as check dams and terracing.

In terms of social organization, Plog (1984) has suggested that the extent of Pueblo I exchange networks may be associated with the need to expand marriage networks between areas with low population densities. Gumerman and Dean (1989) cite this possibility but observe that in the Black Mesa area, exchange systems were too elaborate to be based on the need for marriage alliances alone. They also note that the Western Prehistoric Pueblo area lagged behind its Eastern contemporaries. While the Western Pueblo peoples were still living in pit houses, the Eastern Pueblo peoples in the Chaco and Mesa Verde areas had begun living in large surface pueblos. Gumerman and Dean also point out that when the Western Pueblo I development reached its peak around A.D. 900, Pueblo Bonito was already in existence.

Pueblo II (A.D. 1000–1150)

The Pueblo II period has been well documented in the Western Prehistoric Pueblo area, where sites are numerous and widespread. In addition to the large Pueblo II villages, numerous small homesteads were established throughout the lowland and uplands. This expansion of population likely impacted areas previously used for hunting and gathering. Gumerman and Dean (1989) note that late in the period population levels appear to have stabilized and in some areas, such as Black Mesa, there were declines in population density after A.D. 1000. Nevertheless, it is at this time the Western Prehistoric Pueblo culture reaches its maximum geographical extent. It is also during this time that the Winslow branch differentiates itself from the Kayenta branch and that the Virgin branch reaches its apex.

Intrasite settlement organization becomes highly regular during Pueblo II times. Settlements typically consist of room blocks made of masonry or masonry and jacal living rooms and masonry storage rooms. Some sites have pit houses in combination with masonry structures. One or more kivas and trash mounds are located in front of the room blocks. Many of the smaller sites lack kivas, suggesting that some of the larger sites may have functioned as centers for the ceremonial activities of nearby hamlets and farmsteads. Nevertheless, most Western Pueblo II communities appear to have been self-sufficient units in terms of daily life and survival.

Despite the autonomous appearance of the Pueblo II villages, intercommunity interaction and exchange for raw and finished goods were fairly intense early in this period. However, this pattern gives way to more and more localized procurement and exchange (information and goods) as the different branches of the Western Prehistoric Pueblo become differentiated. Exchange for raw and finished items from beyond the Western Prehistoric Pueblo area drops off dramatically as well.

Subsistence was again primarily from farming. Population increase and spread appears to have reduced the areas available for hunting and collecting and probably reduced the availability of such resources in general. Check dams, terracing, and other water-management features appear to have been commonly used in many areas, undoubtedly reflecting population increase and the need for intensification of agricultural production.

Pueblo III (A.D. 1150/1250–1300)

The beginning of the Pueblo III period is a time of transition and change. To the east the Chaco culture collapses, and there is evidence of a decrease in rainfall and the onset of drier conditions. Specifically, the time between A.D. 1150 and 1175 is a time of extended drought conditions. In general, the first 100 years of this period are not well known, but the last 50 years are undoubtedly the most intensively investigated in Kayenta branch prehistory. Numerous sites, including cliff dwellings, have been recorded and investigated. Notable cliff dwelling sites include Betatakin, Kiet Siel, and Antelope

House. In the Kayenta branch area, the late Pueblo III times are designated the Tsegi phase. Early on, most of the sites consist of U-shaped are masonry room blocks with four or five habitation rooms, storage rooms, and two circular kivas. Also found are sites with scattered pit houses and masonry-lined kivas. During the Tsegi phase a settlement hierarchy with three levels appears to have existed. At the bottom were small farming hamlets located near arable land, and at the top were a few larger pueblos that seem to have functioned as central storage (food and water), communication, and possibly refuge centers for multiple communities.

Material culture reflects a heavy reliance on agriculture. Turkeys were kept, probably mostly for their feathers. Local lithic sources, most of which were of minimal quality, provide the raw material for projectile point production. The ceramic technology of the Tsegi phase flourished. The local ceramic tradition exhibits influences from neighboring Southwestern populations, and there appears to have been a significant exchange of pottery as well. Evidence of long-distance exchange is seen in the presence of turquoise, nonlocal ceramics, and copper bells.

There appears to have been a significant reduction of hunting and gathering during the Tsegi phase, as few limited-activity sites date to this time. There is a clear increase in agriculture and a clear intensification of agricultural practices. Water- and soil-control features are widespread and are far more common in the Kayenta and Little Colorado River areas than in previous times. Extensive systems of terraces, check dams, linear borders, and ditches date to this time and are most common in the Navajo Mountain area (see Lindsay et al. 1968). Gumerman and Dean (1989) note that such water control features are rare and likely unnecessary in the eastern Kayenta lowlands because of the natural concentration of surface runoff and alluvial groundwater.

Also of great importance during the Tsegi phase was the use of reservoirs for the collection and storage of domestic water, especially in the eastern lowlands (Gumerman and Dean 1989:123). Many of the lowland sites are clearly located near springs, tanks, and reservoirs. The need to settle near or construct such facilities may have been tied to a drop in local water tables. Overall, the late Pueblo III period appears to have been a time of increased manipulation of water.

Pueblo IV (A.D. 1300–1600)

Relatively little work has focused on this time period north of the Little Colorado River. Nevertheless, by the end of the A.D. 1300s, the Western Prehistoric Pueblo area was abandoned. The flight from this region appears to have been orderly, with most portable items removed from sites, and doorways sealed as if people expected to return. The people of the Kayenta area appear to have moved south. joining groups on the southern edge of Black Mesa. Reid and Whittlesey (1997) suggest that a rapid depletion of agricultural lands through erosion was a major contributing factor. Gumerman and Dean (1989) also point out that once people started leaving the area, group size reached a point where it was no longer socially or economically feasible for remaining populations to stay.

Some Kayenta branch peoples moved southward to Point of Pines Pueblo, where they apparently were unwelcome guests. After being burned out, they moved on to the Safford Valley and middle San Pedro River. At Grasshopper pueblo, a small group of Kayenta people were apparently welcomed and eventually integrated into the local society.

Other populations were concentrated on the Hopi Mesas, the Jeddito Valley, and along the Little Colorado. Settlements were located in areas were water was plentiful and near suitable farmlands. Most settlements were large, with several hundred rooms in room blocks that enclosed plazas or were constructed in parallel rows circumscribing an open area that likely functioned as a plaza.

Ceramics reflect a new world view with the introduction of the katsina cult. Elaborately decorated pottery is a hallmark of this period, as are extraordinary murals on the walls of kivas. It has been suggested that the adoption of the katsina cult and the continued concentration of populations was the result of environmental degradation, the point being that environmental stress may have facilitated the acceptance of a cult that emphasized rainmaking and fertility (Adams 1981, 1983). The adoption of the katsina cult had a significant impact on the social organization of communities as well.

Agricultural technology and activities were probably little changed from previous times. However, with populations more concentrated, there was likely a greater intensification of agriculture, and Gumerman and Dean (1989) suggest that there was likely intensification in the construction of reservoirs as well.

By the time the Spanish entered the area, the only representatives of the Western Prehistoric Pueblo tradition that remained were the Hopi, living in villages scattered along the southern edge of Black Mesa. Both then and now, the Hopi practiced an array of agricultural techniques (Hack 1942).

The Mogollon

An interesting and somewhat amorphous group referred to as the Mogollon (Haury 1936; Wheat 1955) occupied the mountains of east-central and southeastern Arizona. They were a mountain people who were well adapted to the environment and circumstances in which they lived. The Mogollon were also extremely well adapted to their economic and social environment, readily borrowing technologies, materials, and ideas from neighboring peoples as they needed. They also accepted into their homelands groups of neighboring peoples (Reid and Whittlesey 1997). As Reid (1989) notes, the Mogollon cultudre has been and remains hard to define. The Mogollon are thought to have developed out of the Southwest Archaic Tradition and first appear as part of a series of widespread early plainware/brownware traditions found throughout northwest Mexico and the southern American Southwest (Foster 1991, 1995). The following summary of Mogollon culture history in east-central and southeastern Arizona is based on Reid (1989) and Reid and Whittlesey (1997).

Early Pit house Period (A.D. 200–600)

The Mogollon defined with the appearance of a brown plainware pottery and true pit houses in which the sides of the pits are the walls. The pit houses were round and dug deeply into the ground. Ground level entries were common. At some sites, pit houses are larger than the other domestic structures; these may have been communal features of some sort. Furthermore, it is possible that some sites may have functioned as central places for larger dispersed communities made up of outlying villages and hamlets. Sites consist of small pit house villages located on hilltops and ridges that could have easily been defended.

During this time, the Mogollon depended heavily on hunting and gathering and were less involved with agriculture than the neighboring Prehistoric Puebloan or Hohokam peoples. In fact, they retained a relatively mobile adaptation, moving village sites frequently. In addition to brown pottery, at this time, ground stone and flaked stone tools including knives and projectile points, were also part of Mogollon material culture.

Late Pit house Period (A.D. 600–1150)

This period was a time of population expansion and regional differentiation. Pit houses continued to be used, but they were rectangular with ramped entries, and great kivas appear at some of the larger villages. Again, these structures seem to have served as central ceremonial features for a number of small outlying villages. Villages moved to valley floors adjacent to suitable arable lands, suggesting a growing dependence on food production and a time of less social and economic uncertainty. Although there are indications of a developing interest in food production, the evidence suggests that hunting and gathering still provided the major part of the diet.

Mogollon Pueblo Period: Reorganization (A.D. 1150–1300)

This is a time of significant change in the Mogollon area, much of which is related to contact with Prehistoric Puebloan groups and the more intensive use of agriculture. Large masonry pueblos begin to appear in eastern Arizona Mogollon sites in the mid A.D. 1200s, but for the most part, small pueblos are scattered across the land. Some of these small pueblos have great kivas. Mogollon pottery consists of brownwares and corrugated wares. Some redwares with burnished black interiors and decorated black-on-white wares also are found, the latter indicating interaction with Prehistoric Puebloan groups. Grinding implements and a variety of stone tools are also part of the artifact assemblage. Some of the large pueblos, consisting of several hundred rooms, show clear evidence of Prehistoric Puebloan migration into the Mogollon area. Architecture now includes the presence of D-shaped kivas, indicating a Kayenta branch presence. There is also evidence that many of these immigrants were driven from the Mogollon pueblos in which they sought refuge. The Mogollon homeland shrank as populations grew, competition for resources increased, and pressure from outside groups constricted available land. It is at this time that we see the appearance of an array of sophisticated dry-farming techniques introduced to maximize water management and crop production.

Mogollon Pueblo Period: Aggregation (A.D. 1300–1400)

This is a dynamic time for the Mogollon of eastern Arizona. Local populations concentrated in larger pueblos of 100 to 1,000 rooms. Prehistoric Pueblo peoples moved into the area in large numbers, as an extended drought forced them out of the Colorado Plateau. Many of these people moved into Mogollon settlements, while others established their own.

With the influx of new people, the Mogollon began to rely more heavily on agriculture, and they learned dry-farming techniques from the Prehistoric Pueblo migrants. Higher population densities and a decline in wild plant and animal foods appear to have pushed the Mogollon into this increased dependence on agricultural foods. In the mid A.D. 1300s the Mogollon responded to the onset of extended drought by establishing satellite communities in marginal areas in an effort to bring more land under cultivation. At this time there is also a shift from horticulture to hunting and gathering by the Mogollon, and this shift appears to have been a rapid one.

The aggregation of people into larger groups resulted in social changes as well. Men appear to have had greater access to resources than females, and the elderly were accorded great respect. Changes in religion and ritual also appear to have occurred during these times. Kivas, ceremonial rooms, and plazas became the centers of an array of ceremonial activity. Nevertheless, life was difficult, with high mortality rates among the children due to nutritional stress (Reid and Whittlesey 1997). By A.D. 1400 the central Mogollon Mountains were abandoned. The Mogollon disappeared from the archaeological record, and as Reid and Whittlesey (1997) note, unlike their Prehistoric Puebloan neighbors, they left no identifiable descendants who persist into historic times.

The Hohokam

The Early Formative (A.D. 1/150–650) and Pioneer (ca. A.D. 650–750) periods *of the Hohokam* culture are characterized by expansion of agricultural efforts, increased sedentism, construction of more substantial pit structures, initial production of plainware (around A.D. 1), redware (around A.D. 450), and decorated (around A.D. 650) ceramics, and the emergence of the Hohokam cultural pattern (Doyel 1993b; Neily, Ciolek-Torrello, and Sterner 1999; Wallace et al. 1995). In the original "long count" Hohokam chronology (Gladwin et al. 1937; Haury 1976), the Pioneer period lasted from 300 B.C. to A.D. 500 and marked the initial appearance of the Hohokam culture. However, the long count chronology has undergone substantial revision, especially with regard to the Pioneer period and the origins and development of the Hohokam (e.g., Cable and Doyel 1987; Dean 1991; Mabry 1998a; Wallace et al. 1995). Most of the original Pioneer period has been re-designated the Early Formative period (also called the Early Ceramic period) in many recent chronologies, and the Pioneer period has been pushed forward in time and shortened to mark what is currently understood as the transition to the Hohokam cultural pattern (Ciolek-Torrello 1995; Doyel 1993b; Mabry 1998a; Neily, Ciolek-Torrello, and Sterner 1999; Wallace et al. 1995; Whittlesey 1995). The exact time of the emergence of the Hohokam pattern is still debated; thus the Early Formative and Pioneer periods are discussed together here to emphasize not only the uncertainty of the transition but also the apparent continuity in development.

Early Formative Period (A.D. 1/150–650)

Evidence suggests that a shared cultural pattern existed across southern Arizona during the first part of the Early Formative period (around A.D. 1/150–450/550), referred to variously as the Red Mountain (Phoenix Basin), Agua Caliente (Tucson Basin), and Peñasco (Safford Basin) phase (Cable and Doyel 1987; Ciolek-Torrello 1995; Doyel 1993b; LeBlanc 1982; Mabry 1998a; Neely and Crary 1997; Neily, Ciolek-Torrello, and Sterner 1999; Sayles 1945; Whittlesey 1995). This lifeway pattern was characterized by circular, oval, and bean-shaped pit houses, large communal houses, plainware pottery, large projectile points, basin and slab metates, flexed and seated inhumation and primary cremation, and floodwater agriculture. However, these Early Formative settlements were not fully sedentary, as their inhabitants continued the Early Agricultural period strategy of combining floodplain agriculture with wild-plant foraging. Indeed, in areas where Early Agricultural period villages have been recorded, these settlements reflect a general continuity in subsistence-settlement patterns.

During the ensuing Vahki (Phoenix Basin) and Tortolita (Tucson Basin) phases (around A.D. 450/550–650), regional distinctions began to emerge as Early Formative populations embraced new ceramic, architectural, and other material traits along with changes in subsistence-settlement patterns (Ciolek-Torrello 1995; Doyel 1991, 1993b; Whittlesey 1995:474). Diagnostic of these phases is the presence of redware pottery—Vahki Red and Tortolita Red, respectively—produced along with plainwares and a newly developed figurine complex. Other characteristics of this phase include settlements with plaza-oriented layouts; the construction of large P-4 type pit houses; a mortuary pattern characterized by both cremations in pits or trenches and flexed and semiflexed inhumations; and an increased reliance on agriculture (Bernard-Shaw 1990a; Doyel 1991, 1993b; Gladwin et al. 1937:Figures 34 and 35; Haury 1976:68; Wallace 1999; Wilcox et al. 1981).

The Pioneer Period and the Emergence of the Hohokam (A.D. 550/650–750)

The Pioneer period once comprised the Vahki, Estrella, Sweetwater, and Snaketown phases (Gladwin et al. 1937; Haury 1976). However, many researchers now agree that the Vahki (Tortolita) phase is more representative of Early Formative developments in southern Arizona, and they place the beginning of the Pioneer period around A.D. 550/650 with the introduction of decorated ceramics in the Estrella phase (Ciolek-Torrello 1995; Mabry 1998a; Neily, Ciolek-Torrello, and Sterner 1999; Wallace et al. 1995; Whittlesey 1995). However, it should be noted that opinion is somewhat divided not only over the distinction between the Early Formative and Pioneer periods and but even the terminology for the periods (e.g., Doyel 1993a; Doyel et al. 1995; Mabry 1998a).

The hallmark of the Estrella and Sweetwater phases (around A.D. 550/650–700) is the production of red-on-gray and red-on-brown ceramics. Although large, square houses continue to be constructed, they are smaller in size than during the Vahki phase and occur along with smaller structures (Doyel 1991). Based on the limited data available, the Estrella and Sweetwater phases can best be characterized as a continuation of the broad regional cultural development of the Early Formative period. It is for this reason that the transition between the Early Formative and Pioneer periods is ambiguous. The presence of some intrusive elements at Snaketown, including macaws and parrots as well as shell and turquoise, suggests that a broad regional interaction pattern was developing. Along with ceramic incising and the figurine complex, these intrusive elements suggest that cultural differentiation was underway in the Phoenix Basin (Wallace et al. 1995:606). An Estrella and Sweetwater phase occupation is inferred for the Tucson Basin based on the presence of red-on-brown sherds recovered from sites there (Kelly 1978; Layhe 1986; Swartz 1991) and for the Lower San Pedro Valley based on red-on-gray sherds in site assemblages (Masse 1980a; Masse et al. 1997). The contemporaneous Dos Cabezas phase in the Safford Basin (Neely and Crary 1997; Sayles 1945) is poorly documented, although a few sites around San Carlos Reservoir may date to this phase (Black and Green 1995).

Recent assessments suggest that the Hohokam cultural trait complex was not fully developed until the Snaketown phase or even the subsequent Gila Butte phase (A.D. 750–850) of the Colonial period (Wallace 1997; Wallace et al. 1995; Wilcox 1979; Wilcox and Sternberg 1983), although a much earlier origin, around 300 B.C. in the Vahki phase, was originally proposed (Gladwin et al. 1937; Haury 1976). Reflecting the beginnings of an integrated regional belief and ritual system, the Hohokam cultural pattern, initially appearing in the Phoenix Basin, was characterized by the development of large-scale irrigation agriculture, red-on-buff pottery, a distinctive iconography, exotic ornaments and artifacts, a cremation mortuary complex, and larger and more complex settlements. Trash mounds appeared during the Snaketown phase, and one at Snaketown was capped with caliche, possibly a precursor to the later platform mounds (Haury 1976:82). The adoption of public architecture such as ballcourts occurred during the Gila Butte phase. Throughout the pre-Classic period (Snaketown through Sacaton phases), extending from A.D. 700 to around A.D. 1150 or 1200, the Phoenix Basin can be considered the primary focus of Hohokam regional development.

By pushing forward the emergence of the Hohokam cultural tradition, researchers have developed a consensus favoring an in situ development of the Hohokam from an Archaic base (e.g., Cable and Doyel 1987; Doyel 1991; Wallace 1997; Wallace et al. 1995; Wilcox 1979). In contrast, the original concept of the Hohokam saw them as immigrants from Mesoamerica who brought with them an advanced society based on irrigation agriculture, a well-developed ceramic technology, other sophisticated craft industries, and a sedentary lifestyle (Gladwin et al. 1937; Haury 1976). Nevertheless, significant aspects of the Hohokam cultural pattern are Mesoamerican in origin—ballcourts, figurines, copper bells, macaws, pyrite mirrors—but the mechanisms for how they reached southern Arizona are still debated (e.g., Kelley 1966; Mathien and McGuire 1986; Nelson 1986; Wilcox 1991; Wilcox and Sternberg 1983).

Evidence of Hohokam occupation or interaction is first identified outside of the Phoenix Basin during the Snaketown phase. However, these occupations initially appear to be less extensive than those in the Phoenix Basin. In the Tucson Basin and Lower San Pedro Valley, evidence of a Snaketown occupation is limited to a few sites (Craig 1988; Kelly 1978; Masse 1980a; Masse et al. 1997; Swartz 1991; Wallace 1999). The contemporaneous Pinaleño phase in the Safford Basin (Neely and Crary 1997; Sayles 1945) is poorly documented.

Colonial Period (A.D. 750–950)

The Colonial period—divided into the Gila Butte (A.D. 750–850) and Santa Cruz (A.D. 850–950) phases in the Phoenix Basin—is characterized by the establishment of numerous and widespread settlements throughout southeastern Arizona, the adoption of ballcourts as a public architectural component, the expansion of canal systems, and the spread of new material culture and an elaborate mortuary complex (Ciolek-Torrello and Wilcox 1988; Crown 1991; Czaplicki 1984; Debowski et al. 1976; Doyel 1991; Doyel and Elson 1985; Gasser, Weaver, and Bruder 1984; Gasser, Robinson, and Breternitz 1990; Haury 1976; Howard 1993; Marmaduke and Henderson 1995; Neily, Ciolek-Torrello, and Sterner 1999; Wilcox and Sternberg 1983). Settlement patterns reveal increasing differentiation in site size and function (Gregory 1991) and the development of settlement hierarchies along irrigation systems in river valleys (Doyel 1991). Within sites, spatial patterning in groups of structures becomes apparent. For example, habitation sites comprising courtyard groups focused on a mutual extramural work area become a common settlement organizational pattern (Howard 1985; Wilcox et al. 1981). At smaller hamlets and villages, consisting of one or two courtyard groups, trash mounds, cemetery areas, and cooking ovens tend to be arrayed around the margins of the courtyard. At larger villages composed of clusters of courtyard groups, central plazas and communal cemetery and work areas are incorporated into the village structural layout (Howard 1985; Wilcox et al. 1981; Wilcox and Sternberg 1983). Ballcourts had appeared as integrative structures at some villages by the early Gila Butte phase, and then increased in number and areal extent throughout the remainder of the Colonial period. The number and size of ballcourts varied from village to village, suggesting a hierarchical structure within the regional system (Doyel 1991:249; Wilcox and Sternberg 1983).

The appearance and subsequent expansion of "Hohokam" traits in areas peripheral to the Phoenix Basin, including areas where canal irrigation was not possible, initially was viewed as evidence of migration and colonization by Phoenix Basin Hohokam (Gladwin et al. 1937; Haury 1976). In some cases, movement of Hohokam populations into these peripheral areas is evident (e.g., Doyel 1978; Elson et al. 1995; Haury 1932; Mitchell 1986). However, these patterns are also interpreted as representing the integration of peripheral areas into a Hohokam regional system (Wilcox 1979; Wilcox and Sternberg 1983) or religious cult (Doyel 1991; Wallace 1997; Wallace et al. 1995) centered in the Phoenix Basin. This regional network or cult probably was maintained and regulated through the ballcourt system (Doyel 1991), facilitating trade and exchange as well as dissemination of technological (e.g., canal irrigation and red-on-buff pottery) and socio-religious ideas (e.g., cremation mortuary complex). Although groups in the Hohokam region probably were integrated at these higher levels, recent research has highlighted the diversity throughout the region and questioned the utility of any monothetic explanations of a unified Hohokam "culture" (e.g., McGuire 1991; Wallace 1997; Whittlesey 1998; Wilcox 1991).

In the Tucson Basin the Colonial period Cañada del Oro and Rillito phase populations eventually were integrated into the Hohokam regional system (Craig 1988; Czaplicki and Ravesloot 1989; Doelle and Wallace 1991; Neily, Ciolek-Torrello, and Sterner 1999; Wallace, ed. 1999). Although they shared many traits with the Phoenix Basin Hohokam, the Tucson Basin population remained a distinctive variant of the Hohokam system throughout the pre-Classic period (Doelle and Wallace 1991; Kelly 1978). The primary differences include a more diversified subsistence base with less emphasis on irrigation, and a local ceramic tradition that was stylistically similar to Phoenix Basin buffwares but was technologically distinct (Doelle and Wallace 1991; Neily, Ciolek-Torrello, and Sterner 1999). Occupation expanded within southeastern Arizona in Cañada del Oro Valley, with several large villages being established (e.g., Craig 1989; Craig and Stephen 1985; Craig and Wallace 1987; Elson and Doelle 1987; Hewitt and Stephen 1981; L. Huckell 1980; Roubicek et al. 1973; Swartz 1991; Tagg 1985).

Similar patterns are evident in both the Lower San Pedro Valley (Hammack 1971; Masse 1980a; Masse et al. 1997; Tuthill 1947; Wallace and Doelle 1997; Wallace et al. 1999) and the western Safford Basin (Black and Green 1995; Brandes 1957a, 1957b; Doyel 1978; Mitchell 1986; Neely and Crary 1997; Schroeder 1966; Vivian 1964; Wilcox and Sternberg 1983). The Colonial period is well represented in the Lower San Pedro Valley, suggesting an increase in population (Masse et al. 1997). Limited data for the Safford Basin indicate some migration of Hohokam populations into the western part of the Basin (Doyel 1978; Mitchell 1986). Hohokam red-on-buff sherds are found at small communities during the early Colonial period (Gila Butte and Ranch Creek phases in the Lower San Pedro Valley and Safford Basin, respectively), and these areas were clearly participating in the Hohokam regional system by the late Colonial period (Santa Cruz and Talkali phases, respectively), with the establishment of villages with ballcourts, trash mounds, and household and suprahousehold clusters; irrigation agriculture; imported and local red-on-buff pottery; and the cremation mortuary complex. Primary villages exhibiting these patterns include the Big Ditch, Redington, and Tres Alamos sites in the Lower San Pedro Valley and the Ranch Creek Ruin in the western Safford Basin.

Sedentary Period (A.D. 950–1150)

In the Phoenix Basin, the Sedentary period (the Sacaton phase) was a time of continued growth in the number, size, and extent of Hohokam settlements, ballcourts, and canal networks (Crown 1991; Doyel 1991; Doyel and Elson 1985; Gasser, Weaver, and Bruder 1984; Haury 1976; Howard 1993; Wilcox and Sternberg 1983). Many large sites reached their maximum size and complexity at this time. In peripheral drainage areas, the number of villages, hamlets, and farmsteads also increased. By the early Sedentary period, ballcourts were common in the Phoenix Basin and in the peripheral areas as well, as Hohokam influence expanded to its greatest extent (Doyel 1980; Wilcox and Sternberg 1983). It is also during this time that Hohokam exchange and interaction networks reach their greatest distribution, and the amount of exotic materials at large sites may indicate that some social differentiation had developed (Doyel 1991; Nelson 1986). The intensive use of agricultural rock piles for the cultivation of agave and possibly cholla, as well as nonirrigation agricultural intensification, appears to stem from the late Sedentary and early Classic periods (Fish et al. 1992a, 1992b; Masse 1991a:212).

By the end of the Sedentary period, however, the Hohokam regional system appears to have weakened, as ballcourts and many sites in areas outside and on the fringes of the Phoenix Basin were abandoned and populations settled primarily along major drainages (Ciolek-Torrello and Wilcox 1988; Craig 2000; Crown 1991; Doyel 1991; Gasser et al. 1990; Haury 1976; Wilcox and Sternberg 1983). Incipient platform mounds were constructed in the Phoenix Basin, signaling the beginning of a change in public architecture (Gregory 1987; Haury 1976). Some ancestral villages such as Snaketown and Grewe were depopulated, and the populations shifted and reorganized in nearby locations (Craig 2000; Crown 1991; Doyel 1980; Wilcox et al. 1981). Other changes include "an increase in the production of redware pottery, a decrease in the production of red-on-buff, an emphasis on urn cremation burial, and a decrease in the frequency of ornate artifacts" (Doyel 1991:253). These changes are concomitant with the downcutting and widening of the Gila River between A.D. 1020 and 1160 (Waters and Ravesloot 2000, 2001), which may have been caused by several clusters of major flooding events during this interval (Graybill 1999:26–27).

The Sedentary period in the Tucson Basin (Early, Middle, and Late Rincon phase) is well documented (Doelle and Wallace 1991; Neily, Ciolek-Torrello, and Sterner 1999). A general continuation of Colonial period (Rillito phase) trends is evident in the Early Rincon subphase, as the area remained a distinctive component of the Hohokam regional system. A reorganization of settlements occurred in the Middle Rincon subphase, when large ballcourt villages along the middle Santa Cruz River broke up into a series of smaller settlements (Doelle et al. 1987; Doelle and Wallace 1991). Settlements increased in number, and populations expanded into upland and marginal areas; however, it is unclear whether these shifts were accompanied by population growth. Similar patterns are evident within southeastern Arizona (Craig 1989; Craig and Stephen 1985; Craig and Wallace 1987; Elson and Doelle 1987; Hewitt and Stephen 1981; Huckell 1980; Roubicek et al. 1973; Swartz 1991; Tagg 1985). By the end of the Late Rincon subphase, ballcourts and many sites were abandoned, concomitant with the collapse of the Hohokam regional system.

In the Lower San Pedro Valley, the Sedentary period (Sacaton phase) initially witnessed an apparent increase in population and the establishment of new ballcourts and villages (Masse 1980a;

Masse et al. 1997; Wallace and Doelle 1997; Wallace et al. 1999). Inhabitants appear to have been organized into two distinct population centers centered on the ballcourt villages of Big Ditch (at the confluence of Aravaipa Creek and the San Pedro River) and Redington (near the modern town of Redington). These ballcourt communities also were distinguished by their ceramic assemblages. Subsequently, the Lower San Pedro Valley underwent the same middle Sedentary period reorganization seen in other parts of the Hohokam regional system, with the dispersal of villages into smaller hamlets and farmsteads along the river, the cessation of the use of ballcourts, and changes in ceramic and ritual assemblages (Masse et al. 1997; Wallace and Doelle 1997; Wallace et al. 1999). At the end of the Sedentary period, a dramatic transformation occurred as settlements shifted from alongside the floodplain to defensible, higher terrace settings where free-standing structures began to be constructed within compounds—a typical pattern in the subsequent Classic period.

Similar patterns occur throughout the Safford Basin during the Sedentary period (Two Dog and Eden phases). Evidence indicates that several ballcourts were constructed at villages during the Two Dog phase—including a large court at the Buena Vista–Curtis site near Safford—but the majority of settlements were small and dispersed (Black and Green 1995; Brandes 1957a, 1957b; Brown 1973; Doyel 1978; Mitchell 1986; Neely and Crary 1997; Rinker 1998; Sanders 1990; Vivian 1964; Wilcox and Sternberg 1983). Although typical Hohokam "traits," including canals, are found at many sites, it is clear that an indigenous population exhibiting Mogollon-like characteristics was also present in the Safford Basin (Black and Green 1995; Bronitsky and Merritt 1986; Mitchell 1986; Neely and Crary 1997; Rinker 1998). This admixture of traits, coupled with the limited synthetic work on the pre-Classic period in the Safford Basin, precludes definitive statements about this time in prehistory. As in other areas peripheral to the Phoenix Basin, interaction in the Hohokam regional system ended in the late Sedentary period (Eden phase). This development was followed by a reorganization of settlements and exchange networks, as indicated by increased Mimbres Mogollon ceramics in the eastern Safford Basin (Neely and Crary 1997). Other changes such as the first adobe wall construction herald the onset of the Classic period.

Classic Period (A.D. 1150–1450)

During the Classic period, the Soho and Civano phases in the Phoenix Basin, change in the fabric of Hohokam communities was manifested by several factors. Changes culminating during the Soho phase included a shift in burial practices from primarily cremations to inhumations and urn cremations; the development of new domestic architectural forms, including post-reinforced and adobe-walled structures and walled compounds; a further reduction in red-on-buff pottery and an increase in redware pottery production; and a change in regional exchange networks reflected in a shift in the production and distribution of ceramic types and exotic materials (Crown 1991; Doyel 1980, 1991). The Soho phase also saw the decline and eventual collapse of the ballcourt system in the Phoenix Basin and the florescence of another monumental architectural component, the platform mound (Gregory 1987). With roots in the late Sedentary period (Gregory 1991), the platform mound reflected a change in Hohokam community organization that was manifested in settlement systems not only in the Phoenix Basin, but over a much wider region. Although the rapid transformation of the Classic period Hohokam appears dramatic, many of the developments were initiated in the Sedentary period, and some researchers contend the basic cultural patterns remained Hohokam (e.g., Crown 1991; Sires 1987; Teague and Crown 1984). Nevertheless, fundamental changes occurred in many aspects of Hohokam society, and this process is representative of cultural changes occurring across the Southwest at this time (Cordell et al. 1994; Doyel 1993b).

During the Classic period, a hierarchy of settlement types emerged, including villages with only one or a few walled residential compounds, settlements with one or more platform mound compounds, and other compounds (Doyel 1980, 1991). By the Civano phase, specific large settlements, such as Casa Grande, contained one or more platform mounds, numerous compounds, a ballcourt, and a tower or Great

House (Wilcox 1991:262). These various types of Classic period settlements have been postulated to form distinct irrigation communities—sociopolitical organizations consisting of a series of integrated villages that included one or more platform mound villages serving as administrative centers distributed along a single canal or canal system (Gregory 1991; Howard 1987). A substantial Classic period occupation with platform mounds is also evident in the non-riverine area around the Picacho Mountains (Ciolek-Torrello and Wilcox 1988; Czaplicki 1984). Some platform mounds appear to have evolved in function from a non-residential special purpose facility to a residence used by a specific residential group in the Civano phase (Gregory 1987, 1991:167). Salado polychrome pottery, most of which was imported from outside the Phoenix Basin, appears in ceramic assemblages at this time (Abbott and Schaller 1992; Crown 1994). Such developments may reflect increasing social differentiation, and possibly the existence of elite groups controlling and coordinating ritual and agricultural knowledge (e.g., Doyel 1991; Wilcox 1991; Wilcox and Shenk 1977).

The end of the Classic period was marked by the collapse of the system of platform mound communities and the depopulation of the Phoenix Basin. Niales and others (1989) have suggested that the abandonment of these late Classic period communities coincides with a period of drought and flood conditions that substantially reduced or destroyed the irrigation systems on which these communities relied. An abrupt change in community organization and integration stemmed from this collapse; the new pattern was characterized by dispersed rancheria settlements with shallow pit structures, "degenerate" redware, and a mixed subsistence strategy. Some Civano phase compounds may have been reoccupied (Doyel 1991, 1995; Sires 1983; Teague and Crown 1984). This terminal period of prehistoric occupation in the Phoenix Basin has been tentatively defined at several sites and site components as the Polvorón phase (Chenault 1996; Crown 1991; Sires 1983; Teague and Crown 1984). The precise nature and character of this phase and its existence are actively debated (e.g., Doyel 1991, 1995; Henderson and Hackbarth 2000).

During the Classic period in the Tucson Basin (Tanque Verde and Tucson phases), traits such as residential compounds and platform mounds also appeared; but they were manifested in different forms of settlement and community organization (Doelle and Wallace 1991; Neily, Ciolek-Torrello, and Sterner 1999). Following the abandonment of many settlements in the late Sedentary period, new communities with compounds were established both near abandoned site locations and also in previously unoccupied bajada areas such as around the Marana community (Fish et al. 1992a; Neily, Ciolek-Torrello, and Sterner 1999). Several new hillside settlements (trincheras sites) were established along the middle Santa Cruz River that may have served defensive purposes (Doelle and Wallace 1991; Downum 1986). These settlement shifts appear to have been associated with shifts in subsistence emphasizing dry-farming (Fish et al. 1992a). Reorganization in the Tucson phase is evidenced by the abandonment of many Tanque Verde phase sites, followed by intense nucleation around a few locations, that probably were the most favorable for agriculture. This process of aggregation may indicate increasing hostility between the Tucson and Phoenix Basins (Doelle and Wallace 1991). Within southeastern Arizona, in the Cañada del Oro Valley, a similar trend is evident in the Tanque Verde phase, but no platform mounds or trincheras were built (e.g., Craig 1989; Craig and Wallace 1987; Elson and Doelle 1987; Huckell 1980; Swartz 1991). Most of the Cañada del Oro Valley was depopulated in the Tucson phase, when only three villages were occupied along the eastern Tortolita Mountains.

In the Lower San Pedro Valley (divided into the early and late Classic period), the shift to settlement in compounds on the defensible higher terraces that began at the end of the Sedentary period continued in the early Classic period (Doelle et al. 1997; Wallace and Doelle 1997; Wallace et al. 1999). Associated with this shift was the establishment of large dry-farming fields on the high river terraces and lower bajadas. Although settlement was dispersed during most of the early Classic period, populations later aggregated around 11 sites where platform mounds were built in the late thirteenth century (Wallace and Doelle 1997; Wallace et al. 1999). A similar process of aggregation occurred concomitantly in the

Tucson Basin. Most of late Classic period sites in the Lower San Pedro Valley were located on high ridges with steep slopes and were enclosed by compound walls. Some sites further restricted access through the use of fortifications and barrier walls. A clear concern for defense structured this settlement pattern, but the reasons for these patterns are unknown. During this time of aggregation, two waves of Puebloan immigrants from both the Point of Pines–Reserve and Tusayan-Kayenta areas settled in the vicinity of the town of Redington (Clark et al. 1999; Di Peso 1958; Lindsay 1987). These immigrants occupied defensible locations at the periphery of the established local communities. Presently, evidence suggests a dramatic population decline in the valley after the collapse of the aggregated platform mound settlement system circa A.D. 1400.

The beginning of the Classic period in the Safford Basin (Bylas and Safford phases) is marked by the adoption of residential compounds enclosing courtyards and both pit and surface rooms; the use of cobble-reinforced adobe and masonry wall construction; and shifting interaction spheres (Black and Green 1995; Brown 1973; Doyel 1978; Johnson and Wasley 1966; Mitchell 1986; Neely and Crary 1997; Neily et al. 1993; Rinker 1998; Sanders 1990). Although initially proposed based on excavations in the Bylas area (Johnson and Wasley 1966), the Bylas phase has been redefined as a result of recent investigations in the eastern Safford Basin (Neely and Crary 1997; Neily et al. 1993; Rinker 1998; Woodson 1999). Changes in intrusive pottery types indicate that interaction with the Mimbres area was replaced by connections to the Point of Pines–Reserve and White Mountain areas. Agricultural expansion into upland areas was well underway by the Bylas phase (Rinker 1998). The Safford Basin, like the Lower San Pedro Valley, saw an influx of Puebloan immigrants from both the Point of Pines–Reserve and Tusayan-Kayenta areas in the late Bylas phase (Brown 1973; Clark et al. 1999; Lindsay 1987; Woodson 1999). By the Safford phase, the use of pit rooms and compounds decreased and the remaining population aggregated into villages composed of large room blocks (Neely and Crary 1997). Plazas, and in some cases rectangular kivas, replaced courtyards as public gathering places. Salado (Gila and Tonto) polychrome became the dominant painted pottery and was produced locally in the Safford Basin. Similar Classic period developmental patterns are evident in the western Safford Basin in the San Carlos Reservoir area (e.g., Black and Green 1995; Johnson and Wasley 1966; Mitchell 1986) as well as the Globe area (Doyel 1978). Evidence suggests that the Safford Basin was largely depopulated by the end of the Classic period.

Throughout southeastern Arizona, the changes manifested in the second half of the Classic period have traditionally been associated with the Salado culture or the Salado phenomenon. These changes include the adoption of Gila Polychrome, platform mounds, inhumation burial, and room block architecture. The Salado concept has been envisioned variously as a local culture or regional culture area (e.g., Doyel 1978; Wood 1992), an exchange system linking elites from various subsystems (e.g., Wilcox and Sternberg 1983), a powerful segment of society that held leadership roles and dominated neighboring regions (e.g., Haury 1945), or a regional cult (Crown 1994). Other approaches (e.g., Nelson and LeBlanc 1986) to the Salado concept have shown that, other than sharing Gila Polychrome, sites dubbed as "Salado" reveal a high degree of variability in most material aspects. The definition of Salado thus remains problematic. More recent studies (e.g., Elson et al. 1995) argue against the Salado as an archaeological culture, but they support the thesis of Salado as a broad, regional horizon beginning around A.D. 1250.

Salado (Tonto Basin Sequence)

Tucked away in the northeastern home range of the Hohokam is Tonto Basin, the often-cited heartland of the Salado culture (see Dean, ed. 2000; Rice 1990). The concept of Salado as a culture versus a phenomenon versus a horizon remains nebulous, despite a tremendous amount of recent work in the

Tonto Basin (e.g., Elson et al. 1995; Lincoln 2000; Nelson 2000). The following is derived form these sources.

The newest Tonto Basin sequence notes that Preceramic period (11,000 B.C.–A.D. 100) remains are unknown or relatively rare (Dean 2000b; Elson 1996). Paleoindian and Early Archaic remains are not represented in the general project area and are rare in central Arizona as a whole. Middle and Late Archaic remains are more common but not well described or understood.

Recent work in the Roosevelt Lake area has also identified an Early Ceramic period (A.D. 100-600) occupation of the area (Elson 1996). Work at the Eagle Ridge site (Elson and Lindeman 1994) resulted in the identification of an Early Ceramic period component characterized by small bean shaped-and oval pit houses with entries oriented to the southeast. Cotton was being raised, along with corn and beans. The diet also included a variety of wild-plant foodstuffs along with some hunted animals, fish, and fresh-water shellfish (Anodonta). Late Archaic style projectile points, a predominantly sand-tempered, plain brownware ceramic assemblage, basin metates, and a few pieces of shell characterize the artifact assemblage. It appears that the bean-shaped pit houses may be earlier that the oval structures.

Snaketown Phase (A.D. 675/700 to 750)

The revised Tonto Basin sequence now includes a Snaketown phase. Although no Snaketown phase components were identified as a result of the Roosevelt Lake–related work, some sites produced Snaketown Red-on-buff sherds. The presence of Snaketown ceramics in the Tonto Basin has led the Roosevelt Lake project investigators to ponder the question of when the Hohokam may have first expanded into the Tonto Basin. It is possible that this movement may have occurred sometime during the Snaketown phase.

Gila Butte Phase (A.D. 750-850)

Gila Butte phase components are well represented in the Tonto Basin. Hohokam houses-in-pits are the typical form of domestic structure, and these are considerably larger than the preceding Early Ceramic period structures identified in the Roosevelt Lake project sites. In the Upper Tonto Basin some Mogollon-like pit house architecture has also been identified. Some of the Gila Butte pit houses appear to be organized into courtyard groups, while others show no particular orientation or clustering. Small quantities of a local red-on-buff ware were produced, and a local sand-tempered, plain brownware accounts for less than 20 percent of the utility wares. Gila Butte Red-on-buff occurs as an intrusive ceramic type, and a nonlocal micaceous schist-tempered plainware makes up more than 70 percent of the utilitarian ceramic assemblage. Overall, Hohokam buffwares account for 15 to 20 percent of the ceramic assemblage. Other artifact types include projectile points, palettes, stone bowls, censers, and Glycymeris shell bracelets and shell beads.

Cultigens identified include corn, cotton, and squash. Wild plants exploited include cholla, saguaro, prickly pear, tansy mustard, amaranth, chenopodium, little barley, and grasses, and agave is more commonly used than in previous times. Rabbit, deer, fish, and some *Anodonta* supplement the plant-based diet. It is argued for the Lower Tonto Basin that the presence of Hohokam-style pit house architecture and the high frequency of nonlocal Hohokam ceramics is a clear indication of Hohokam expansion (migration) into the Lower Tonto Basin. It is further suggested that local indigenous populations were not, or at least not totally, displaced by the Hohokam but adopted a Hohokam lifestyle. The local population is thought to have been relatively small.

Santa Cruz Phase (A.D. 850-950)

The Santa Cruz phase in the Lower Tonto Basin is not well understood. Architecture, intrasite settlement organization, and the general cultural pattern established in the Gila Butte phase appear to carry over into the Santa Cruz phase, although Santa Cruz phase pit houses may be somewhat larger. It is not clear how extensive Hohokam migration into the Lower Tonto Basin may have been during this time. Secondary cremation burials in defined cemetery areas become the typical form of burial.

Sacaton Phase (A.D. 950–1050)

Sacaton phase components are well represented in the Lower Tonto Basin. Domestic architectural styles carry over with houses increasing in size. Small hamlets, farmsteads, and some field houses are present. Pit houses may or may not be organized into courtyard groups. Larger-than average pit houses are present, and they may have served as some form of communal or integrative structures. There is increased use of corn, cotton, and squash, and beans and grain amaranth are identified for the first time. There is an intensification of the use of agave, and it is suggested that agave may have been cultivated. Wild plants continue to contribute to the diet and there is an apparent decrease in the quantity of game animals. Juniper is commonly used in construction, indicating the exploitation, for the first time, of an ecozone above 4,000 feet in elevation. No decorated ceramics appear to have been produced locally. Redwares appear for the first time, and the majority of redwares and plainwares are thought to have been produced in the Tonto Basin. Sacaton Red-on-buff is the dominant intrusive type; some Cibola White Ware types are more common. The majority of sand-tempered plainware ceramics were manufactured in the Tonto Basin. Other common artifact types include small, unnotched, serrated projectile points and shell bracelets, beads, and pendants. Secondary cremations in defined cemeteries appear to be typical of this phase. By the end of the Sacaton phase Cibola White Wares dominate. It is suggested that these changes are the result of reorganization of the Hohokam regional system and the expansion of the Chacoan system.

Ash Creek Phase (A.D. 1050-1150)

The Ash Creek phase is the terminal pre-Classic period phase in the Tonto Basin. It is distinguished from the earlier Hohokam sequence in the Lower Tonto Basin because Hohokam Buff Wares are replaced by Cibola White Wares. In most respects, the lifestyle and cultural pattern represented in the preceding Sacaton phase continue. Utilitarian wares are mostly plain, and no Tonto Basin-made brownwares or locally made decorated wares have yet been identified. Cibola White Ware types are the most common intrusive types with a few Little Colorado White Wares and a variant of Sacaton Red-on-buff. Other classes of artifacts appear to carry over from Sacaton phase times. Secondary cremations continue, but for the first time since the Early Ceramic period inhumations are also represented.

Miami Phase (A.D. 1150–1250)

In the Lower Tonto Basin the beginning of the Classic period is defined by the Miami phase. The temporal placement and diagnostic characteristics of this phase are difficult to identify. As Elson and Gregory (1995:72) note, this phase is defined by some architectural changes and the lack of certain ceramic types. It is also important to note that the Miami phase is defined as a result of the recent research in the Roosevelt Lake area and is an important and significant redefinition of the term as used by Doyel (1978). It is, however, still seen as a pre-Salado and pre–platform mound occupation of the Lower Tonto Basin. Although the use of pit houses appears to continue during this time, there is evidence for the first use of aboveground masonry architecture with masonry compounds probably replacing pit houses or pit house clusters. No integrative architecture has yet been defined or identified for this phase. Hamlets with several related compounds, along with farmsteads and field houses, typify the settlement pattern. The ceramic assemblage is poorly understood. Utility wares are mostly Tonto Basin plain brownwares, with some redwares (not Salado) and corrugated wares. Intrusive ceramic types present include Snowflake, Reserve, Tularosa, and Walnut A black-on-white; St. Johns Polychrome, and McDonald Corrugated. Walnut B Black-on-white is also present. However, in virtually all instances, the contexts of these intrusive types are problematic and their dates overlap with either earlier or later phases. Therefore, to date, they have not been particularly useful in helping to define the Miami phase. The same can be said for other artifact classes. Cremations and inhumations are thought to continue based on their presence in both the earlier Ash Creek phase and the subsequent Roosevelt phase.

Roosevelt Phase (A.D. 1250–1350)

The Roosevelt Lake projects have been particularly helpful in better defining the Roosevelt phase. This time span appears to represent the most intensive occupation of the Tonto Basin. Masonry compounds and pueblo-like room blocks are typical domestic architecture. The first platform mounds appear in the late A.D. 1200s, and two varieties, the Meddler type and the tower type, are known. Large village-level settlements occur along with hamlets, farmsteads, field houses, and specialized, limited-activity sites. Domesticated foods provide a substantial portion of the diet. Agave is quite common, and it is almost certain that it was being cultivated during this time. Cotton is also abundant, and it is thought that some sites may have been specializing in its production. Hunting provides even less of the diet than in earlier times. *Anodonta* continues to be used for food and sporadically for ornament manufacture. There is an emphasis on the use of high-elevation species such as pine and fir for construction, with a decrease in the use of mesquite. For the first time there is local production of Tonto Basin decorated ceramics; Pinto Polychrome and Pinto Black-on-red appear. Local brownwares continue to be produced but redware and corrugated ware types, including Tonto Corrugated, Salado Red Corrugated, and Salado White-on-red, dominate the utility ware assemblage. Little Colorado White Wares no longer occur as intrusives, while added to the intrusive assemblage from preceding times are Pinedale Polychrome, Pinedale Black-on-red, and Cedar Creek Polychrome. Changes in other artifact classes also occur. The shell assemblage includes a greater variety of species, and *Conus* tinklers are common along with *Olivella* shell beads. Cremations and inhumations continue, and it appears that inhumation became a more common practice during this time. Portions of the Tonto Basin are being abandoned by the end of the Roosevelt phase.

Gila Phase (A.D. 1350–?)

The extent of the Gila phase occupation of the Tonto Basin appears to be greatly diminished from the preceding Roosevelt phase. Populations aggregate into larger compounds and multi-storied pueblos. Platform mounds continue to be constructed. Cliff dwellings and occupation of mesa tops occur for the first time. It is suggested that populations concentrated in areas that could sustain larger population densities (Ciolek-Torrello et al., 1994:594). The Gila phase is also defined by the presence of Gila and Tonto polychromes, which replace Pinto Polychrome and earlier black-on-white types. This time period is also marked by the presence of White Mountain Red Wares and the Hopi Yellowwares, in particular Jeddito Black-on-yellow, as intrusive types. A major point of debate regarding the Gila phase focuses on the nature and complexity of Salado social organization. The presence of large, architecturally complex platform mound sites at fairly regular intervals has led some (e.g., Rice 1990) to argue for a highly structured sociopolitical system, while other have suggested lesser levels of sociopolitical organization as a more realistic assessments of Salado society (e.g., Whittlesey and Ciolek-Torrello 1992). Whatever the case, it does appear that the Gila phase is an outgrowth and intensification of the earlier Roosevelt phase. Furthermore, the Salado phenomenon is clearly of considerable interest, in that it is manifested in what is probably the most recognizable and spatially extensive ceramic horizon in the Greater Southwest. By the A.D. 1400s all this seems to have collapsed. Whether the collapse was the result of climatic conditions, drought and catastrophic flooding, degradation of the local environment due to over-exploitation by its inhabitants, or perhaps some political or economic cause, is not fully understood.

It is clear that the prehistory of the Tonto Basin was dynamic and complex. Whether the Salado represents a development out of peoples indigenous to the Tonto Basin but variously influenced by their Hohokam, Anasazi, and Mogollon neighbors, or whether they were a divergent Classic period Hohokam population influenced by their neighbors, or something else, remains an open question.

The Sinagua

The Sinagua culture (Colton 1946) is centered in the Flagstaff area of north-central Arizona and includes the central part of the state from the Verde Valley to Winslow. The following summary is derived from Landis (1993), which is in turn a summary of Hohmann (1983), Landis (1991, 1993), and Pilles (n.d.).

Colton (1946) saw the Sinagua as a distinct cultural entity more closely related to the Mogollon than to any other culture, although as Martin and Plog (1973) note, many of the features at Sinaguan sites resemble those of the Kayenta branch Prehistoric Pueblo culture to the north and northeast. The Sinagua appear to have been an amalgamation of several cultures. They likely began as a local population living primarily in pit houses. However, they fled the area with the eruptions of Sunset Crater in the A.D. 1060s. These eruptions covered over 800 km2 with black volcanic ash that eventually created a mulch that acted to conserve moisture and enhanced the land's agricultural capacities. As local populations returned to the area, there may have been an influx of nonlocal peoples, who brought with them elements of Prehistoric Pueblo, Mogollon, and Hohokam culture (Colton 1946; Wilcox 1986). Despite the presence of external elements and influence in the area, many researchers believe the Sinagua were very much an indigenous development (e.g., Bruder et al. 1989; Fish, Pilles; and Fish 1980; Pilles 1979; Wilcox 1986). In sum, the Sinagua are seen primarily as an indigenous population with significant changes toward greater complexity in social organization and stratification between the Angell-Winona and Elden phases (Hohmann 1983:63-73).

Cinder Park (A.D. 500-700) and Sunset (A.D. 700-900) Phases

Cinder Park and Sunset phase pit houses occur individually or in groups of two to three (Hohmann 1983). They are circular and subsquare, with lateral or antechamber entries and four to six large roof supports (Pilles 1969). They may have had tipi-like superstructures, and most were faced simply with plastered earth, although some had walls lined with timbers in floor grooves (Breternitz 1959; Colton 1946).

Rio de Flag Phase (A.D. 900-1050)

Rio de Flag phase pit houses also occur individually or in small clusters. However, the number of pit houses can be up to seven or eight, forming small hamlets. Late in the phase, pit houses generally were deeper, and had ventilator shafts, and roof entries were common, as were alcove houses.

Wooden structures were built on the surface of earthen mounds that may or may not have been natural features. Surface masonry structures also appear in the Rio de Flag phase. Masonry structures near pit houses may have been for storage, while those found in isolation are interpreted to be field houses. Some unusually large pit houses have been identified and are suggested to be ceremonial or community structures (Hohmann 1983).

Angell-Winona Phase (A.D. 1050-1100)

Originally this phase was two phases, based on two distinctive house forms identified at a series of sites in the Winona Village complex. These two pit house types appear to have strong Mogollon

(Angell) and Hohokam (Winona) influences. Nevertheless, they are temporally contemporaneous. The Mogollon-style pit houses often have masonry retaining walls and wall poles extending from ground level to the roof. The Hohokam-style pit houses are subrectangular, with lateral entries and wall poles extending from the floor to the roof (Hohmann 1983).

Sinagua pottery (Sunset Red, Sunset Brown, and other Alameda Brown Wares) was made primarily by coiling and scraping, and after the eruption of Sunset Crater, crushed cinder was used as temper. Much of the pottery and other artifacts found at Sinagua sites consists of exchange items (Prehistoric Pueblo, Hohokam, Mogollon, and Patayan pottery). Hohokam influence is also seen in the presence of Angell-Winona phase ballcourts; of which there may be as many as 14 in the Flagstaff area (Fish, Pilles, and Fish 1980). What are thought to be large community rooms also have been identified. By late Angell-Winona phase times, sites ranged in size from isolated habitations to large villages of six to eight clusters of habitation structures consisting of two to four habitation features with an associated trash mound or two. Many of these villages had some communal feature, either a ballcourt or a large community room, associated with them (Hohmann 1983).

There was a substantial post-eruption population increase during the Angell-Winona phase. Hohmann (1983) has suggested that is was part of a similar trend noted throughout the Southwest at this time rather than some local phenomenon.

Padre Phase (A.D. 1100-1130/1150)

Architecturally, the Padre phase is typified by the presence of large, deep, rectangular masonry pit houses with flat roofs and usually with ventilators. Surface masonry structures were also used for habitations as well as for storage and field houses. Large community rooms were still common, but there was a decline in the use of ballcourts. Settlement patterns and material culture carry over from late Angell-Winona phase times (Hohmann 1983).

Elden Phase (A.D. 1130/1150 – 1250)

During the Elden phase, masonry pueblos of one to 70 or more rooms became the dominant form of habitation. However, pit houses continued to be used, as did some of the large communal rooms, some of which appear as rectangular kivas. These structures may represent Mogollon influence. A few ballcourts continued in use as well. Some of the major Elden phase sites may have been redistribution centers that affected economic, political, and social activities in the area. Hohmann (1983) argues that burial data indicate increased social differentiation at this time.

Turkey Hill (A.D. 1250–1300) and Clear Creek (A.D. 1300–1400) Phases

The last two phases of the Sinagua sequence are not well understood. During the Turkey Hill phase, population aggregation seen during the Elden phase is merely assumed to have continued. The Clear Creek phase typically was a time of further aggregation into massive masonry pueblos of 40 to over 1,000 rooms. Agricultural activities were intensified and contributed to the overall cultural complexity. By A.D. 1400, the Flagstaff area was abandoned completely, as were other large regions of the Southwest. Whether the abandonment was due to soil depletion, drought, social friction, or some combination of these and/or other factors is unknown.

Honanki (A.D. 1130–1300) and Tuzigoot (A.D. 1300–1400) Phases

These phases are associated with the southern Sinagua. It is during this time that the upper reaches of the Verde Valley are abandoned by the Hohokam. Over time, people abandoned the smaller villages and aggregated in a few large pueblos such as Tuzigoot and Montezuma Castle. The ceramic assemblage associated with these phases lacks the corrugated pottery found to the north, and it is not clear if the decorated pottery was produced locally or brought in from the Flagstaff area. Near the Roadhouse Ruin, which is near Horseshoe Reservoir, the prehistoric inhabitants of the area constructed extensive rock alignments and rock piles to maximize the use of rainfall. In addition, they fished and captured freshwater mollusks, waterfowl, beaver, and muskrats. By A.D. 1400 the area was abandoned (Breternitz 1960; Colton 1946).

Patayan

Another cultural group occupied areas of the Lower Colorado River and portions of the western desert and Papaguería. This group, known as the Patayan, has not been extensively investigated, and, as a result, their culture history and adaptations to the arid environs of the Colorado River valley and western Arizona are not well understood. Lower Colorado Buff Ware ceramics, the hallmark of the Patayan tradition, provide a rough although disputed chronology. Redwares and stucco-coated plainwares, shallow basin metates, and triangular projectile points are also characteristic of Patayan assemblages (Rogers 1945). Summaries of Patayan culture history include those of McGuire (1982), Reid and Whittlesey (1997), Simonis (2000), C. Stone (1986, 1987), D. Stone (1991), and Waters (1982a, 1982b). This summary draws from these works. The Patayan culture is divided into two groups, the Lowland Patayan (River Patayan) of the lower Colorado River Valley and the Upland Patayan of the northern Colorado River Valley and western desert of Arizona.

Lowland Patayan Culture History

Patayan sites are found in a broad area extending from the deserts of southern California to the Buckeye Hills east of Gila Bend. Evidence of Patayan presence extends south to the Sierra Pinacate, Mexico and north to Parker, Arizona. However, very few of these sites have been thoroughly investigated or reported. The absence of site data means that "there is little archaeological evidence on which to base reconstructions of Patayan settlement, subsistence, and organizational patterns" (Stone 1986:68). A combined riverine and upland adaptation similar to that of the ethnographic Yumans is inferred for these groups. Although the lack of stratified sites prevents direct demonstration, material culture inventories and settlement pattern evidence indicate continuity between Patayan and Yuman groups. Many Patayan villages are assumed to have been destroyed, inundated, or buried by the Gila and Colorado rivers.

The origins of the Patayan culture of the Colorado River valley are unclear. The main reason for this is the lack of work in the area. Patayan sites are found along the Gila River from Yuma to the Agua Caliente Mountains, in the western Papaguería, and in the Gila Bend area (McGuire 1982; Vivian 1964; Wasley and Johnson 1965). During the period from about A.D. 900 to 1100, the Patayan expanded eastward. Many of the sites are small special-use loci for the collection and processing of wild plant foods (Goodyear 1975). Rodgers (1976) further suggested that there was an environmental distinction between Patayan and Hohokam sites with Patayan ceramics/sites more common in the upper bajada and mountain zones and Hohokam sites more common on floodplains and in bajada locations. McGuire (1982:220) suggested that big Patayan habitation sites are located on the floodplain of the Colorado and Gila rivers. Little more is known of the origins of the upland Patayan.

The Lowland Patayan sequence is divided into three phases beginning around A.D. 700 (Rogers 1945; Waters 1982a). Rogers believed the appearance of the Patayan occurred with the introduction of ceramics from Yuman speakers from southern California or non-Yuman speakers from the Papaguería or Sonora. He rejected the notion that ceramic technology was introduced from the Hohokam area.

Patayan I (A.D. 700 and 1000)

Patayan I is defined by the presence of three major ceramic types: Black Mesa Buff, Colorado Beige, and Colorado Red. Decorative techniques include notched rims, lug and loop handles, the so-called "Colorado shoulder," and incising. Patayan I peoples were apparently highly mobile and actively engaged in trade. The Willow branch site produced pottery, shell, steatite, asphaltum, and turtle shell rattles from California (Stone 1986).

Patayan II (AD 1000-1500)

Dramatic changes in ceramics signal the start of the Patayan II period. Patayan II ceramics found in the Mojave Desert, north on the Colorado River, and along the Gila River east to Aqua Caliente are believed to indicate the widespread expansion of Patayan groups, perhaps in response to the immigration of other groups and/or internecine warfare along the Colorado River (Stone 1986).

Patayan III

Few ceramic changes mark the start of the Patayan III period and the protohistoric and historic occupation of the area. After the demise of the Hohokam, Patayan/Yuman populations are believed to have spread east along the Gila River until they reached the distribution observed by Spanish explorers in the eighteenth century.

The history of interaction between Hohokam and Patayan groups started as early as the Sedentary period, when Patayan ceramics first occur at Hohokam sites in the Gila Bend area. Throughout much of the Sedentary and Classic periods, Gila Bend marks the boundary between the distribution of Lower Colorado and Hohokam ceramics. This area is seen as an important locus for the interaction and intermixture of these two cultural groups.

Upland Patayan culture history has traditionally been expressed in three cultural manifestations, the Cohonina, Cerbat, and Prescott (Bair and Stoker 1994; Colton 1939a; Euler 1958; Landis 1993; Schoreder 1961, 1979; Simonis 2000; Stone 1987). The Cerbat occupied the area in the big bend of the Colorado River near Needles, California, the Cohonina occupied the area south from the Grand Canyon to the San Francisco Mountain volcanic field, and the Prescott occupied the area in and around the city of Prescott, Arizona. To say the least, there is much debate regarding the organizational and cultural historic systematics used to discuss the archaeology of the Upland Patayan. Although this summary takes a more traditional approach, the reader it referred to Simonis (2000) for an alternative model of the area's prehistory. Landis (1993) also presents a detailed discussion of Cohonina prehistory, one that is heavily drawn upon in the following discussion.

Upland Patayan Culture History

The Cerbat

The Cerbat branch, first defined by Colton (1939a) and then redefined by Euler (1958), is poorly understood. The primary defining trait of the Cerbat is Tizon Brown ware ceramics (Aquarius Brown, Cerbat Brown, and Sandy Brown), which were made from about A.D. 700 to 1900 (Simonis 2000). Simonis notes that these types, which exhibit a range of surface colors from gray to orange and are defined primarily by temper type, are very difficult to distinguish from other Patayan ceramic complexes (Cohonina, Prescott, and Lower Patayan). Other Cerbat artifacts include a crunching slab, a specialized slab milling stone that was used into historic times by the Pai. The earliest period of Cerbat prehistory is referred to as the Desert period, which is suggested to begin about A.D. 700 and last to A.D. 1150 (Euler 1958, 1982). Little is known of this period, and virtually nothing is known of settlement and subsistence patterns. Stone (1987) suggests that the Cerbat may have practiced a transhumant pattern of farming and mesquite foraging near the river during the summer and wild-plant resource exploitation and hunting in the mountains during the other months. Implicit in this suggestion is that the Cerbat practiced some form of floodplain, rainfall, perhaps water table (groundwater), or runoff agriculture.

Euler (1958) has argued that the Cerbat began moving out of the Colorado River valley eastward onto the Colorado Plateau between A.D. 1150 and 1300 (Territorial Expansion period), replacing the Cohonia culture, and that they are the direct ancestors of the Hualapai and Havasupai. Euler's model has been questioned as a result of subsequent radiocarbon dates for Tizon Brown Ware that indicate a Cerbat presence (if Tizon Brown Ware equals a Cerbat presence) in the uplands well before the A.D. 1150 date. The dates are from the Date Creek area (A.D. 400) and from near Bagdad (A.D. 655 and 835; Linford 1979; Simonis 2000).

The Cohonina

The Cohonina were initially defined as a Patayan branch by Colton (1939a) based on the distribution of San Francisco Mountain Gray Ware. Others (Cartledge 1979; Euler and Green 1978; Sullivan 1986) argue that the Cohonina are more closely related to the Kayenta branch of the Prehistoric Pueblo culture of northeastern Arizona. Sites from along Deadman Wash, an area seen as a cultural frontier with Kayenta, Sinagua, and Cohonina elements (e.g., Colton 1946; Parry 1981; Samples, Hanson, and Wilcox 1990), provide the basis for the initial description of the Cohonina. McGregor (1950, 1951, 1967) conducted work in the Cohonina core area near Williams and Mount Floyd on the southern Colorado Plateau and at sites on Red Butte on the south rim of the Grand Canyon (Landis 1993).

Ceramic cross-dating and a few tree-ring dates indicate that the Cohonina occupation of the plateau extended from approximately from the mid A.D. 700s to 1200. The earliest reliable tree-ring dates are a set of 21 specimens from NA 5166, northwest of Williams, that date between A.D. 772 and 775 (see Euler 1982; McGregor 1951:20; Robinson and Cameron 1991:4). This was the only site McGregor assigned to the Naylier phase. However, a characterization of and the temporal span of the Naylier phase remain undefined (Landis 1993).

The Coconino and Medicine Valley phases, dating from A.D. 700 to 900 and A.D. 900 to 1100, respectively, were defined for the area north of Flagstaff (Colton 1939b). Temporally, these date ranges are equivalent to the Prehistoric Pueblo I and II periods. Subsequently, while working on the Sinagua, Colton (1946) added a Hull phase (A.D. 1100-1200) to the Cohonina sequence. The Hull phase included the use of masonry pueblo architecture. The Cohonina phase was also applied to sites in the area west of Flagstaff and near the Grand Canyon (McGregor 1950, 1951). McGregor also proposed a Cataract phase, A.D. 950 to 1050. However, no effort was made to compare the Cataract phase to the eastern Medicine Valley phases. McGregor (1965:250-251) observed that Coconino phase Cohonina lived in shallow, circular pit houses, while the western Cohonina lived in rectangular surface rooms organized in a linear fashion with an associated pit structure. For the Mount Floyd vicinity McGregor (1967:28-72) reported pit houses, simple rock outlines, patio houses, possible sweat houses, and unit structures of a pit house, a ramada, and continuous long rooms, many of which had storage pits and hearths. To him, this cluster of features indicated a year-round occupation of the structures. Also present were check dams and numerous manos and metates, indicating a strong reliance on agriculture.

The Hull phase may be only an eastern Cohonina manifestation on the Coconino Plateau. The Cohonina appear, for the most part, to have left the Coconino Plateau by A.D. 1150 to 1200. However, as Landis (1993) points out, this interpretation is based on the disappearance of intrusive Kayenta ceramics from Cohonina sites, which may indicate a disruption of exchange rather than an abandonment of the area. However, Landis also observes that Cohonina sites dating to this apparent abandonment period may simply remain unrecognized. Tizon Brown Ware is found at Cohonina sites as a trade ware, and it also occurs on the Coconino Plateau in association with Hopi ceramics by A.D. 1300 to 1400. The Hopi wares could have been traded into the area, or Hopis could have brought them there as traders or settlers, or both. Historically, the Pai and the Hopi both have used parts of the Coconino Plateau.

The Cohonina are often described as having a limited and unimpressive material culture, albeit a fairly varied one. The so-called Cohonina projectile points are elongated and triangular with slightly serrated edges (McGregor 1951:111). These points may be late in the Cohonina sequence, possibly dating only after about A.D. 900. Also common on Cohonina sites are large, stemmed, corner-notched, and side-notched points, usually thought to be from the Archaic period. These may have been made by the Cohonina, or picked up and curated by them, or both (Landis 1993). Cohonina pottery is typically San Francisco Mountain Gray Ware, but includes the types Deadmans Gray, Deadmans Fugitive Red, Deadmans Black-on-gray, Floyd Gray, Floyd Black-on-gray, and Kirkland Gray as well (Colton 1958). Trade wares on Cohonina sites include Kayenta, Sinagua, Cerbat, and Prescott types. Other trade items include obsidian and red ochre.

Cohonina architecture consists of shallow pit houses, ramadas, alcove houses, patio houses, masonry rooms (at least at the wall bases), granaries, unit structures, and “forts.” This variability in architecture is particularly notable after A.D. 900. Hearths and storage pits are not common, and the storage pits are small, indicating that the Cohonina had little to store. Site types include habitations, "forts," and camps for hunting, gathering, or both. Water-control features associated with the Cohonina include check dams, diversion walls (linear borders), and cleared garden areas.

Cohonina sites are concentrated in the piñon woodland areas that ring the Coconino Plateau. The central grasslands are virtually devoid of sites, although there are secondary concentrations of sites at the margins of ponderosa forests and a few in the open juniper woodlands (Landis 1993). Sites frequently appear in clusters adjacent to water sources on the lower mountain slopes, and there are also agricultural and rock art sites.

There is a significant lack of information regarding Cohonina subsistence activities. Sites located in piñon and piñon-juniper woodlands indicate a reliance on the gathering and processing of piñon nuts. Corn and squash have been found, and the presence of grinding implements suggests a level of reliance on agriculture. Faunal remains are not common, which is surprising, considering the abundance of projectile points, knives, and scrapers in the lithic tool assemblages. However, it does appear that a variety of animals, including antelope, deer, jackrabbit, cottontail rabbit, bighorn sheep, bobcat, domestic dog, rattlesnake, squirrel, gopher, and prairie dog, were hunted.

The groups that occupied Cohonina sites may have been local, autonomous bands whose intragroup organization probably varied based on the number of people living there. Nuclear families likely occupied single-room sites, while extended families lived at sites with multiple rooms. Some burials, although few have been recovered, indicate that there may have been some acknowledgment of status within groups. Little is known of the decline and disappearance of the Cohonina.

The Prescott

The most recent summary and discussion of Prescott archaeology is that edited by Motsinger, Mitchell, and McKie (ed. 2000). Their review is summarized here. As these authors note, the Prescott “culture” is also referred to as the Prescott branch of the Patayan (Colton 1939a). Schroeder (1979) believed it developed from a Hakataya base, and others have suggested it is an indigenous development heavily influenced by neighboring groups such as the Hohokam, Patayan, Cohonina, and Sinagua (e.g., Breternitz, 1960; Fish and Fish 1977; Pilles 1981). Some also see it as southern Sinagua (e.g., Downum 1992; Pilles, 1981). For the purposes of this brief summary, Prescott culture history is included within the overall framework of the Patayan.

Early Formative Period (ca. A.D. 200–600). This recently identified time period in Prescott prehistory is characterized by shallow pit houses, plainware ceramics, a ground stone assemblage that is transitional from Archaic to Formative, and Cienega-style projectile points. It appears to be similar in nature to the Early Agricultural period in southern Arizona. Sites have been identified along Big Bug Creek and the upper reaches of the Agua Fria drainage. This period appears to be a redefinition of Breternitz's (1960) Squaw Peak and Hackberry phases.

Agua Fria Phase (A.D. 600–850). The indigenous peoples along Big Bug Creek and in the Agua Fria drainages see an influx of Hohokam colonists during this time. The Hohokam occupation appears to be limited to the upper Agua Fria drainage and perhaps Skull Valley. Some sites have both Prescott and Hohokam pit houses on them. Hohokam influence seems to have been substantial.

Prescott Phase (A.D. 850-1050). The origin and development of the Prescott phase is not well understood. This phase is defined in areas not colonized by the Hohokam, although some Hohokam influence is nevertheless present. Defining characteristics include formal, earthen-walled pit houses, Prescott Black-on-gray pottery, and greater formalization of material.

Copper Basin Phase (A.D. 1000-1150). Motsinger, Mitchell, and McKie (2000:6-7) propose this provisional phase to account for sites that appear to be transitional between the earlier Prescott phase and the following Chino phase. This phase is defined on the presence of stone-outlined pit houses that postdate earthen-walled pit houses but predate sites with stone-outlined pit houses and masonry architecture. Associated material culture has not yet been identified.

Chino Phase (A.D. 1100–1300). The Chino phase was originally defined based on the presence of masonry or adobe architecture. Motsinger, Mitchell, and McKie (2000:7) suggest that a village type also found during this phase includes a mix of pit houses and small pueblos and call it the pit house/pueblo hamlet. A hilltop fort type of settlement is also said to be present. It is possible that the pit house/pueblo hamlets, which are associated with large numbers of figurines and located in the ponderosa forests south of Prescott, may have been occupied by a different ethnic group.

Willow Creek Phase (A.D. 1300–1500?). This phase is poorly understood and is defined based on a radiocarbon date that suggests that a remnant prehistoric population existed in the area prior to the appearance of the Yavapai. It is generally believed that most of the Prescott area was abandoned around A.D. 1300.

SUMMARY

Clearly, Arizona prehistory is long, varied and complicated. Humans have pursued a living in the semi-arid and arid environs within this state for at least 11,000 years. From the late Pleistocene hunters to the ceramic period Puebloan dwellers, water has played a varied and critical role in their survival. From simple watering holes to rock piles to extensive and complicated irrigation systems, without a doubt the history of the use and manipulation of water in prehistoric Arizona is one of the more unique records in the Southwest and North America.

CHAPTER 3

NON-IRRIGATION AGRICULTURAL WATER MANAGEMENT TECHNIQUES AND PROPERTY TYPES

Michael S. Foster

> Archaeologists have long been intrigued and perplexed by features on the Southwestern landscape that can best be described generically as rock alignments. Such features are typically found on gentle slopes or in association with shallow, ephemeral streams–either across them in higher elevations or on the floodplains of arroyos in lower elevations. They are situated perpendicular to slope or stream in series ranging up to a few dozen. Construction involves rocks being piled without mortar. The features vary in height, width (thickness), and length, but are usually less than knee high, a half-pace wide, and a few paces long [Doolittle, Neely, and Pool 1993:7]."

This chapter describes a variety of non-irrigation farming techniques that utilize and manipulate rainfall in a number of ways. These techniques are variously represented in the archaeological remains in the Sonoran Desert as well as those of the uplands of northern and eastern Arizona. Because significant ambiguity exists in the term <u>dry farming</u>, and what it does and does not include, the term <u>non-irrigation farming</u> agriculture is used here. Furthermore, this discussion focuses on techniques that include both rainfall directly on fields and crops as well as runoff from rainfall, and that employ a level of land modification or water manipulation (diversion techniques) not seen in floodwater farming (see Chapter 4).

As Crown (1984a) notes, the highly visible and extensive irrigations systems in the Hohokam area of central and southern Arizona have been, and are, the focus of considerable study and speculation (see Chapter 5). Until relatively recently, the remains associated with the so-called "alternative" farming techniques have been either generally overlooked or relegated to minor roles or backup strategies in prehistoric subsistence activities. Nevertheless, over the last two decades, as more and more non-irrigated agricultural sites have been identified and investigated, it has become clear that such sites contributed significant amounts of food, in both primary and secondary roles, to the subsistence of the prehistoric peoples of Arizona. Furthermore, although individual feature types are described and discussed below, non-irrigated agricultural sites are often composed of multiple feature types that probably functioned as components of larger runoff-control and conservation systems (Doolittle 1984; Homburg 1997:124).

At this point it is also worth noting the difficulty in reconstructing prehistoric agricultural systems (Ciolek-Torrello et al. 1990:28; Doolittle, Neely, and Pool 1993). As these investigators state, advancement in the study of prehistoric agricultural systems is fraught with problems involving the identification of farming sites, functional interpretations, and temporal assessment. Furthermore, most food-producing activities leave no easily discernible remains. An example of this can be seen in Russell's (1977) study of traditional Navajo agriculture in which he found that less than 10 percent of the fields he examined had any soil- or water-control features that might be identified by archaeologists after the field was abandoned. In other words, the features discussed below, although important to our understanding of prehistoric water control and agriculture in Arizona, likely represent a relatively small portion of the agricultural system(s) of any given group of people. Furthermore, many, but certainly not all, of the field systems identified, based on overall size and number of features, are likely the product of family-size production units.

PROPERTY TYPES

This section describes a group of prehistoric features or property types utilized for water management and conservation in non-irrigation agriculture. These property types have been defined as described by various investigators (e.g., Glassow 1980; Masse 1979, 1991a; Rankin 1989; Vivian 1974) over several decades. Many of the terms have been used in different ways by different authors, and one of the goals of this document is to reduce some of ambiguity in terminology and bring more uniformity to discussion of these property types.

Over the last several decades, as archaeological investigations in Arizona have expanded, our knowledge and understanding of where and when these various property types came into use and what they were used for have grown as well. Today we have a detailed knowledge of the variety of water management techniques employed by the prehistoric inhabitants of the region. We also have a good understanding of what was grown on and in these features. This is not to say that there is not yet a great deal to be learned, but most of the recent efforts have resulted in a better understanding of the spatial and temporal distribution of these features. In fact, one of the most impressive results of the work of the last few years is the documentation of the abundance and geographical scale of these features.

It is important to note that although one might identify a single or small cluster of rock piles or a series of two or three check dams, these features frequently occur in combination with other types of water-control devices (e.g., Fish 1995). In other words, several of these features were often used in combinations that formed larger field systems. Rock piles, for instances, are frequently found with contour terraces, as are check dams.

The explosion in research, particularly in the last 10 to 15 years in conjunction with cultural resource management, has resulted in the identification of hundreds and hundreds of sites with non-irrigation water-management features. This is especially true in the Hohokam area, where, for example, rock piles are a ubiquitous feature or site type. In the discussion of the various property types below, the goal is to present good examples of each property type and to cite some of the major works in which they are identified and discussed. The spatial and temporal summary discussions, as well as the distributional maps, generally tell where and when these feature types occur. To discuss every little valley or drainage or hillslope where these features have been documented would take several reams of paper and not add substantially to the goals of this document.

Rock Piles

Rock piles are probably the most widely and commonly documented non-irrigation agricultural features in the Hohokam region of central and southern Arizona (Figure 3.1). Although they have been recognized for nearly three decades (e.g., Canouts 1975; Duering 1973; Kearns et al. 1975), intensive study of these features is a relatively new phenomenon. A considerable body of literature now exists documenting the presence and investigation of these features.

In addition to being a common agricultural feature in the Hohokam area, rock piles are also found in other parts of Arizona including the Wupatki National Monument area of northeastern Arizona (Travis 1990). They do not, however, appear to be a common feature in the pueblo-dwelling areas of northern Arizona. Furthermore, rock piles as agricultural features are not unique to prehistoric Arizona. They have also been found in the neighboring Great Basin (Irwin-Williams et al. 1986), and there are Old World examples of such features in the Negev Desert (Evenari et al. 1982).

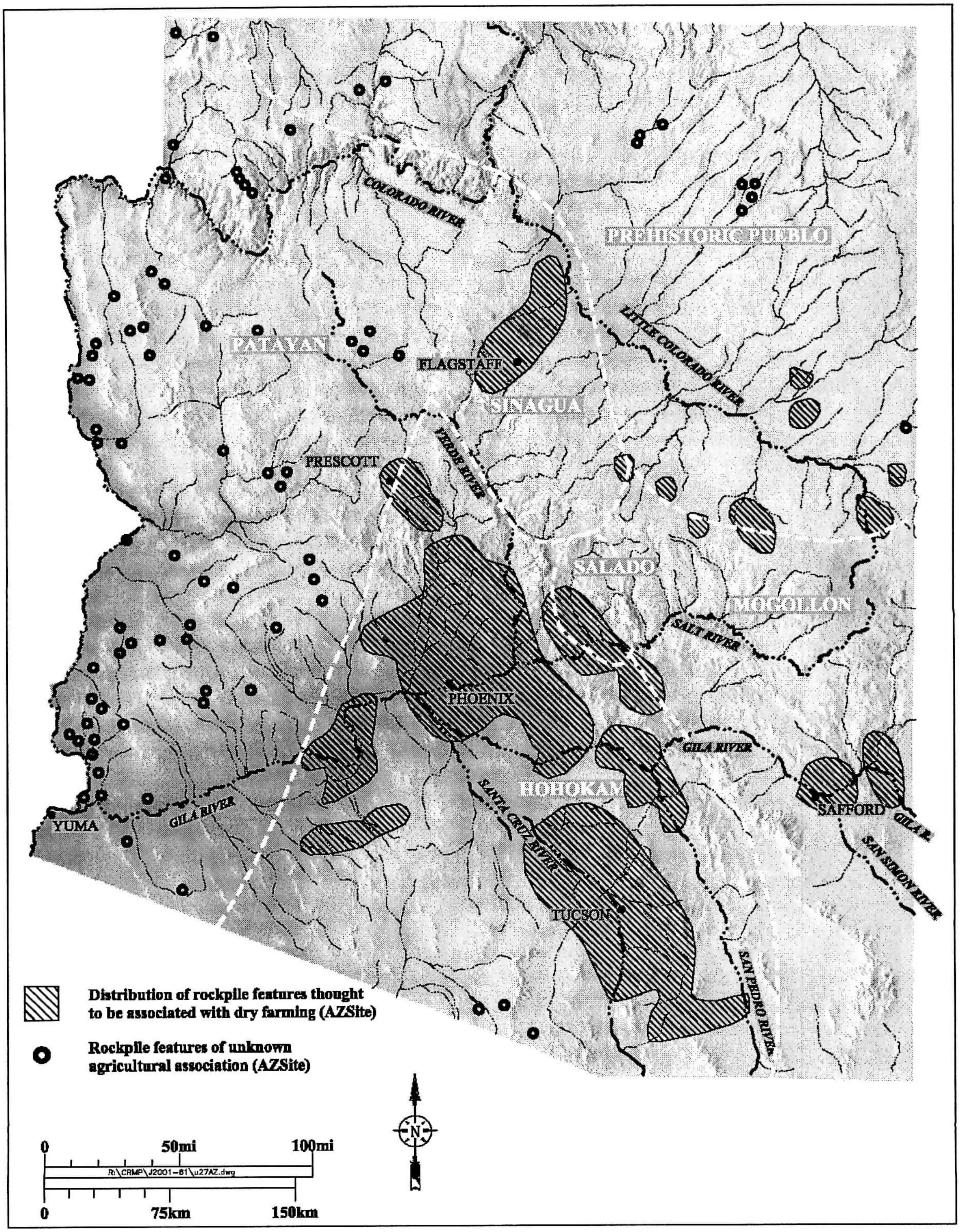

Figure 3.1. Distribution of rock pile features in Arizona.

Rankin (1989) notes that although commonly called rock piles, they have also been variously referred to as cobble clusters (Dart 1983a), cobble rock piles (Doyel and Elson 1985), rock clusters (Debowski et al. 1976), rock mounds (Spoerl 1984), and stone piles (Rice et al. 1979). Rock piles generally appear as low conical- or dome-shaped piles of cobbles that come in varying sizes from less than 1 m to over 10 m in diameter (Masse 1979:164; Figure 3.2 and 3.3). The height of rock piles generally varies from a minimum of 5 cm (the thickness of a single layer of stones) to 35–50 cm. Fish, Fish, and Madsen (1992:76) note, however, that they rarely exceed 1.5 m in diameter and 75 cm in height. Most frequently, they are less than 1 m in diameter. The features themselves appear as a jumble of stones of various sizes simply tossed into a cluster. The stones are unmodified and range in size from gravels to pebbles to cobbles to small boulders in excess of 50 cm in diameter. Masse (1979) notes that some rock piles appear to have been constructed by filling in a pre-established ring of large stones. The materials from which the rock piles are constructed generally appear to come from the surrounding area.

These features also occur in a variety of environmental settings, as isolated features, or small dispersed or concentrated clusters of features, or as numerous features in fields. Several meters or more usually separate individual rock piles. Some localities, such as Tumamoc Hill and the Marana community, contain hundreds or thousands of rock piles (Fish, Fish, and Madsen 1992; Masse 1979). They are found on gravel terraces above streams and rivers, on the slopes of bajadas, and in the alluvial plains of washes and ephemeral streams. In the Marana area, fields containing rock piles ranged in size from 10 to 50 ha (Fish, Fish, and Madsen, eds. 1992), within an area of 480 ha. Kearns and others (1975) observed that rock pile fields are found over areas as large as 324 ha in the Verde Valley area.

The most common and intensively investigated explanation for rock piles is that they are agricultural features on which, or around which, plants were grown (e.g., Fish, Fish, and Madsen, eds. 1992). Fish, Fish, and Madsen note that the uneven and porous surface of rock piles makes for a permeable area that more readily absorbs rainfall and runoff. They also indicate that the composition of the rock piles reduces evaporation and facilitates the retention of soil moisture, thus producing a mulching effect, citing evidence from the Negev Desert of Israel (Evenari et al. 1971) to support this assertion. They also note that rock pile features today very often contain concentrations of annuals, perennials, lichens, and mosses that require considerable amounts of moisture and they have verified this observation by comparing root biomass beneath rock piles and in adjacent control area. Fish, Fish, and Madsen also note that rock piles appear to reduce rodent predation, as it is difficult for animals to burrow for access to roots and stems.

Fish, Fish, and Madsen (eds. 1992) argue that the rock piles in the Marana area were used for the cultivation of agave and that this was a response (intensification) to increasing population and higher demand. Crown (1984:12a) notes that corn and cotton pollen have been recovered from areas between rock piles and that corn pollen was recovered from the soil beneath a rock pile (Fish 1983). Cholla is also frequently cited as a plant grown on or around rock piles. Similar, although not as extensive or well dated, remains are reported for the nearby Los Robles community near Cerro Prieto (Downum 1993).

Another rock pile study of particular interest is that of Purcell and others (1997), who studied a series of *sites in the* Middle to Upper Gila River valley along a Salt River Project transmission line right-of-way (Coolidge to Hayden). These investigators began by establishing a typology for the rock piles (see also Doak et al. 1994) that included non-agricultural and agricultural features (Table 3.1; Figure 3.4). Most of the rock piles recorded in the Coolidge to Hayden project area were Types 3, 4, 5, and 7. Purcell and others (1997) compared their data to those of the Sanchez Copper Project (Doaks et al. 1994), where most of the rock piles were Types 3, 4, and 5, and found a similar pattern. Prior to excavating the rock

Figure 3.2. Typical rock pile feature in the Marana survey area prior to excavations (photograph courtesy of Paul and Suzanne Fish).

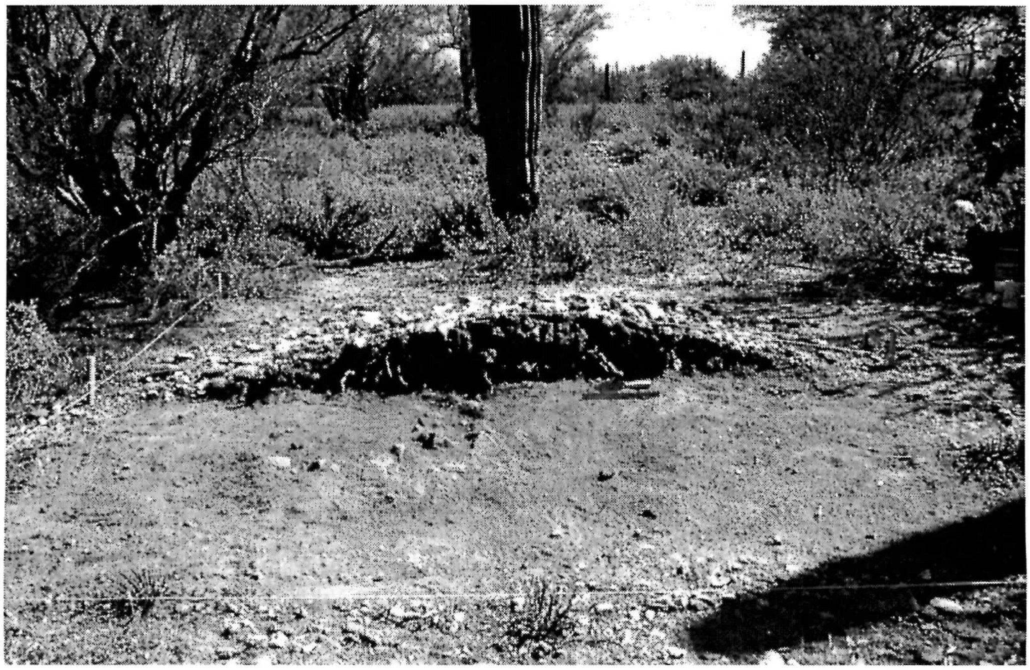

Figure 3.3. Same rock pile feature after excavation (photograph courtesy of Paul and Suzanne Fish).

piles Doaks and his colleagues also documented the presence of both living and dead vegetation on the features. Although several procedural problems affected the results, it generally appeared that from 38 percent to 66 percent of the rock piles at a given site had vegetation growing on them. One case is of particular note. At AZ V:13:145(ASM), a large Mormon tea plant (Ephedra sp.) was growing out of one rock pile; Ephedra was not observed on any other part of the site.

Purcell and his colleagues took detailed measurements (size and volume) of each rock pile. Based on these measurements and observations of the local geomorphology, they report " that sites with rocks of smaller grain size, and with less loose rock on the ground surface, will tend to have rock piles smaller in area and volume than rock piles on sites at which relatively large rocks are available in abundance" (Purcell et al. 1997:5.13). They note that this conclusion is generally supported by previous field observations made by other investigators (e.g., Cantley 1991; Doelle 1976; Fish et al. 1985).

Purcell and others (1997) excavated 16 rock piles at five sites. In these cases, it was often difficult to identify stratigraphic differences between the sediments whether the rock piles and those underlying them. Each of the rock piles excavated was sampled for macrobotanical and pollen remains. The samples were taken from withinin the rock piles when sediments were present; otherwise from the sediments at the base of the rock piles. The researchers also attempted to estimate the time required to construct the rock piles by measuring the volume of rocks used (through water displacement), the time it took them to excavate the rock piles, and then the time it took to replace the rocks once the feature had been excavated and sampled. They concluded that estimating volume through the water displacement method was not particularly useful. Nevertheless, they estimated that the rock piles in their project area probably required about 2 person-hours to construct.

In an attempt to glean even more information from their rock pile sites, Purcell and others (1997:5.14–5.22) completed microtopograpic mapping of several of the fields from which to generate 3-D topographic maps with rock pile locations noted. The goal was to determine if such detailed data might provide new information on the distribution of individual rock piles. They did note differences between their sites, but these were clearly due to differences in local topography. Despite the fine 3-D maps generated, Purcell and others concluded that their efforts were not particularly productive and that no new insights were gained. The technique was time consuming and expensive, and the conclusions they reached were no different from the careful field observations reported by previous investigators (e.g., Cantley 1991; Doelle 1976).

The Coolidge-Hayden study provides one last example into the utility of detailed studies of rock piles. The pollen, phytolith, and flotation samples taken from seven rock pile features indicated clearly that they served as pollen traps, with the modern local vegetation well represented (Purcell et al. 1997:5.22). Information on prehistoric use and function was extremely limited. A possible Zea mays cob-type phytolith was identified, as well as some maize pollen and edible weed plants, including Cheno-ams. But, overall, the results were ambiguous. These analyses did suggest that the assemblage of environmental remains recovered was indicative of disturbed conditions associated with prehistoric fields. Overall, Purcell and others (1997:5.13) concluded "that with the methods and technology currently in use, archaeological excavation of rock piles is unproductive."

Table 3.1. Rock Pile Typology.

Type	**Description**
Type 1: Marker Stone	A single stone, or one stone resting entirely on top of another, too insubstantial to have served any purpose other than marking a spot.
Type 2: Very Small Rock Pile	Three or four rocks clustered tightly into a cairn; like Type 1 presumably too small to have served as anything more than a marker.
Type 2A: Pot Rest or Basket Ring	Three or four rocks arranged with an open space at the center; arrangement of stones suitable for holding a vessel with a rounded base upright. Stones tend to be smaller than in normal Type 2 features.
Type 3: Small Rock Pile	Three or four rocks measuring 1.5 m or less in diameter and having a generally insubstantial appearance.
Type 3A: Small Sorted Rock Pile	A few rocks of a uniform and fairly large (ca. 20- to 30-cm-diameter) size, in a tight cluster measuring less than 1 m in diameter. More substantial in appearance than the normal Type 3 rock piles; forms the smallest component of a continuum of similarly sorted features, along with Types 4, 7, and 8.
Type 3B: Gravel-Mulched Rock Pile	(only one example was noted) Typical Type 3 rock pile with an open space in the center that has gravel spread over it. While such gravel-mulching has been noted in the past in waffle gardens (see Vivian 1974:97), this is the first time it has been noted in connection with a rock pile feature.
Type 4: Compact Rock Pile	A fairly compact cluster of stones measuring 1-2 m in diameter. Stones are of a fairly consistent size (large cobbles), shape tends to be more-or-less circular.
Type 4A: Rock Jumble	Similar in size and composition to Type 4, but much more densely packed with cobbles, to the extent that rocks are resting entirely on rocks rather than the ground surface. Contexts suggest that they might be of modern origin or naturally produced by rockfalls; however, no direct evidence for either of these presumptions exists.
Type 5: Disrupted Rock Pile	Measures 1–3 m in diameter, stones of a much less uniform size than in Type 4, less regular shape. Smaller examples piles are similar in many respects to Type 3; distinction was based largely on a perception of disturbance in the Type 5 specimens–that is, the rocks appear to have once formed a tighter cluster than they currently do, whereas Type 3 examples appear to have been built as they now are.
Type 6: Dispersed Rock Pile	Measures up to 3 m in diameter, made of fairly small (diameter <20 cm) cobbles. Stones do not give the impression of being massed, but rather of having been spread out across the ground surface.

Type	**Description**
Type 7: Large Rock Pile	Large concentration of rocks, 2–4 m in diameter. Morphologically like larger examples of Type 4 or 4A. Some mounding at the center tends to occur. [These were observed at one Coolidge to Hayden site, AZ V:13:148(ASM), but were not subjected to more detailed investigation than recording.]
Type 8: Very Large Rock Pile	Concentrations of cobbles and boulders, 4 m or more in diameter. Also similar in form to Type 4 or 4A: stones of a fairly uniform size are used, closely packed together into fairly regular clusters. Displays a more notable degree of mounding in the center than smaller piles, although excavations did not suggest any particular significance to this phenomenon.
Type 9: Rock Scatter	Fairly small stones spread out over a fairly large (but unspecified) area. General appearance of roasting pits, but no direct evidence of burning; no ash or obvious fire-cracked rocks present.

(Doaks et al. 1994; Purcell et al. 1997)

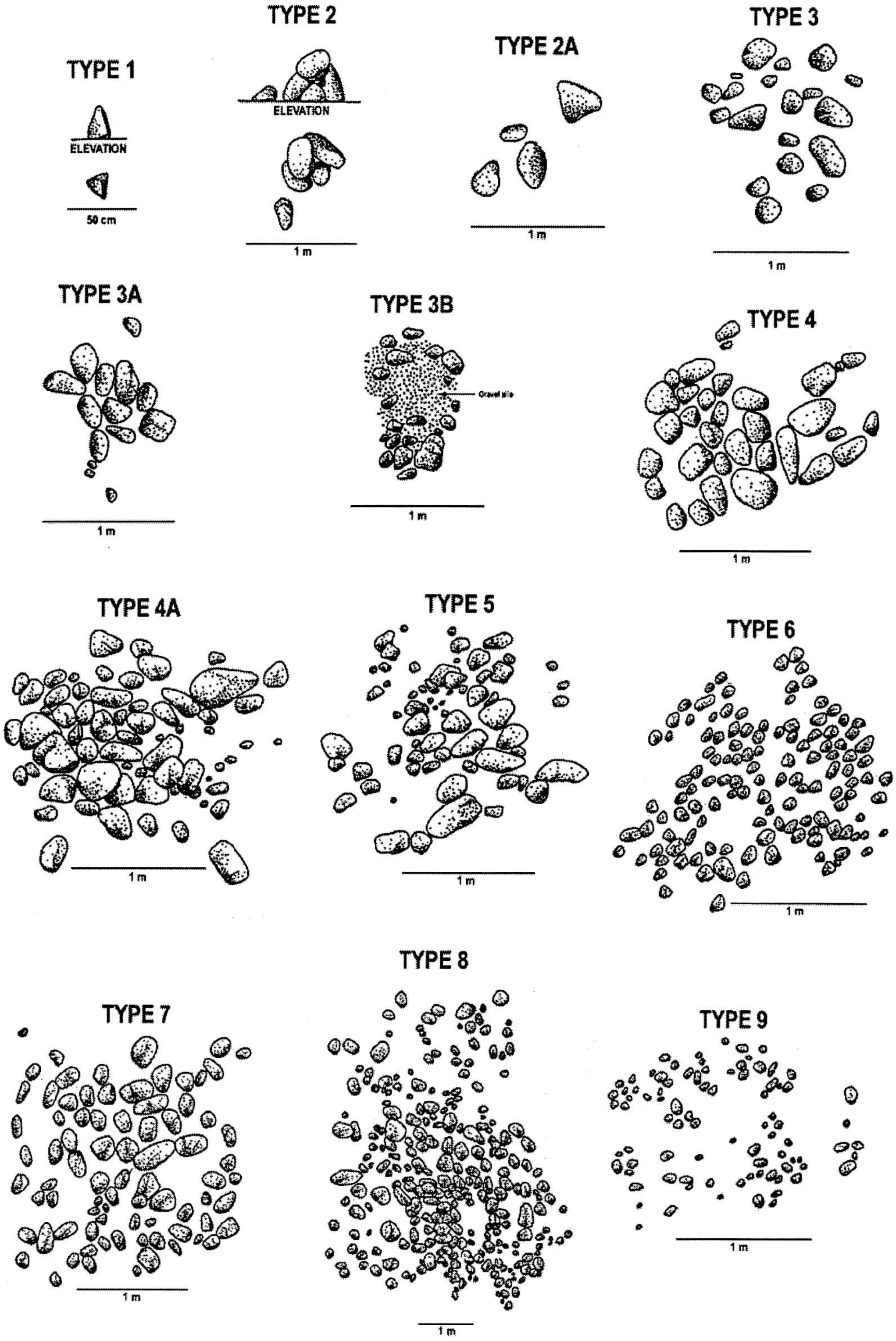

Figure 3.4. A rock pile typology (adapted from Doak et al. 1997).

Although their function as agricultural features has been well demonstrated, other functions have been ascribed to rock piles as well. Some researches suggest they are the byproduct of field clearing or of land clearing to facilitate rainfall runoff, or that they were created to retard runoff or as field markers. Masse (1991a:2210-211) suggests that rock piles are the products of two distinct types of activity that are largely temporally discrete. He proposes that rock pile features dating primarily between A.D. 900 and 1050 were more likely produced as a result of land-clearing activities, to augment runoff for fields located downslope, noting the association of rock piles at Tumamoc Hill (Masse 1979) with areas containing high quantities of surface gravel and rock. A second agricultural function of rock piles, as planting beds, Masses sees as restricted primarily to the late Sedentary and early Classic periods (ca. A.D. 1100–1250), although some may date as early as the late Colonial period (Craig and Wallace 1987). Travis (1990) identified a number of features related to agricultural at Wupatki, including rock piles. He suggests that the rock piles in the Wupatki area may have functioned as field boundary markers, erosion control devices, scarecrow supports, plant protection devices, or field shrines, or that perhaps they were nothing more than field-clearing residue. Rankin (1989:973) also notes that rock piles may have functioned as nutrient traps. She observed that organic debris, such as grasses, twigs, and small branches, often became trapped in rock piles during monsoon and winter storm runoff events at sites in the Waddell Project area northwest of Phoenix. It is assumed that the decomposition of such organic debris would provide nutrients for any plants growing in or next to the rock pile. However, such runoff events could also have caused the loss of soil from rock piles and facilitated the leaching of nutrients from the soil.

Cultural and Spatial Distribution

Rock pile features appear to be a hallmark of Hohokam non-irrigation agriculture and thus, are most common in central and southern Arizona, in the northern Tucson Basin, the lower Verde River valley, portions of the lower Salt River valley, Middle Gila River basin, and the Northern Periphery areas. These features occur as isolated individual rock piles, or as clusters of rock piles, or in extensive rock pile fields containing hundreds of the features.

In northern Arizona, rock piles identified in the Wupatki area are associated with the Sinagua culture following the eruption of Sunset Crater in A.D. 1064 or 1065. Rock piles used as water-control or agricultural features do not generally appear to be associated with the prehistoric Puebloan peoples of northern Arizona. This is not to say, however, that they are absent in a prehistoric Puebloan context. For example, one rock pile feature, located at the Cactus Rock Gardens site in the Navajo Mountain area just north of the Arizona-Utah border, is reported by Lindsay and others (1968:188). It was described as a pile of naturally rounded pieces of sandstone 15 cm high and 1 m in diameter, located between two linear borders recorded at the site. This rock pile is interpreted as a "planting hill." and it was suggested that it served to protect young plants from blowing sand. The site is thought to date between A.D. 1150 and 1300.

Interestingly, Masse (1980b), in his discussion of non-irrigation agriculture at Gu Achi southwest of Tucson, noted the presence of rock piles, but at that time he had rejected the use of such features by the Hohokam. Subsequently, the Salt-Gila Aqueduct Project resulted in the recording and investigation of numerous rock pile sites, and corn and cotton pollen were recovered from rock piles at several of these (Crown 1984b). Several sites in the Mazatzal area north of Sunflower also contained rock pile features (Green 1990). Several features were tested, and pollen from several wild economic taxa was recovered; however, the association between the pollen and the features is equivocal. Mitchell (1998) reports on several sites in the foothill area of northern Scottsdale (the Cave Creek and New River areas) that contain both rock piles, which are common, and contour terraces (see also Potter 2000:170–171). Doelle, Dart, and Wallace (1985) reported rock piles at agricultural sites along the Santa Cruz River south of Tucson, and Marmaduke and Robinson (1983) identified rock piles during the Chuichu survey at the northeastern edge of the Papaguería. Stone (1991) mentions the presence of rock piles and alignments in the Lower Colorado River valley area, but their function as agricultural features is ambiguous.

Temporal Distribution

Direct dating of rock pile features is often difficult because of the lack of associated temporally diagnostic artifacts, and when such artifacts are present, their association with the rock pile feature or field may be tenuous. Furthermore, there is often a lack of material suitable for chronometric dating. These features, however, are clearly associated with the sedentary agricultural portion of Arizona's prehistory. To date, no evidence of rock piles dating to the late Archaic or early Formative periods and the beginnings of agriculture have been identified. Rock piles in the Hohokam area appear to date between ca. A.D. 900 and A.D. 1300/1350.

As previously discussed, Masse (1991a) has suggested a temporal range for rock pile features in the Hohokam area of A.D. 900 to 1250, with rock piles dating from A.D. 900 to 1050 being generally associated with field clearing and rock piles dating A.D. 1050 to 1250 being associated with agricultural activities (specifically the production of agave). In the Marana Community area, Fish, Fish, and Madsen (eds. 1992) associate large-scale agave cultivation with early Classic period expansion at circa A.D. 1100 to 1150. Gasser and Kwiatkowski (1991) note that agave horticulture appears to have become more important during the Classic period in the northern Tucson Basin (Fish, Fish, and Madsen, eds. 1992). However, they point out that similar evidence for a dramatic increase in the cultivation and use of agave was lacking for the lower Salt River Valley. Miller (1994) however, reports an increase in the use of agave at Pueblo Grande from pre-Classic period through Classic period times, although the increase was not dramatic and paralleled an increase in population size. Furthermore, Miller makes a point of the fact that most of the agave found at Pueblo Grande came from small hearths and thermal pits and not large processing features (hornos). Nevertheless, rock pile features are common in the lower Salt River Valley and in adjacent areas along the "northern periphery" and the lower Verde Valley (e.g., Homburg 1997; North, Lack, and Foster 2001).

Homburg (1997) suggests that rock piles may have been more common in the pre-Classic period in portions of the lower Verde Valley, while in other areas they were more common during the Classic period. In terms of the pre-Classic period sites, rock piles are associated with Santa Cruz/Sacaton sites on the east side of the Verde River at the mouth of Camp Creek. The point is that rock pile fields were in widespread use as early as A.D. 800 to 900 in the lower Verde Valley. Homburg (1997) clearly indicates that the pre-Classic period rock piles in the lower Verde Valley are agricultural; thus, Masse's (1991a) suggestion that most pre-Classic period rock piles are residue from field clearing may be overstated. In the northern Tucson Basin, rock piles and agave horticulture are thought to be predominantly associated with the early Classic period occupation of the area (Fish, Fish, and Madsen, eds. 1992). Rankin and Katzer (1989) indicated a similar time range in the Agua Fria Waddell Project area as well.

Dating of the rock pile features in the Wupatki area is somewhat problematic, but generally they appear to be post-eruption (Sunset Crater), dating no earlier than the late A.D. 1000s or early A.D. 1100s (Period 2; Downum and Sullivan 1990:5.10). Many of the smaller villages in the area were abandoned during the early to mid A.D. 1200s, and thus it is possible that use of the agricultural sites, including the rock piles, was primarily restricted to the time between the late A.D. 1000s and mid A.D. 1200s. Some of the larger villages, such as Wupatki itself, continued to be occupied for a time, and it is likely that outlying agricultural fields and their features continued to be used.

Associated Features

Rock piles are often found in association with other non-irrigation agricultural features including check dams and contour and bordered terraces (e.g., Fish, Fish and Madsen 1992a, 1992b; Homburg 1997; Huckell 1990; Travis 1990). Also found in association with rock piles are roasting pits (hornos), which were used to roast the hearts, inflorescences, and leaf bases of agave (Castetter, Bell, and Grove 1938; Fish, Fish, and Madsen, eds. 1992). Isolated field houses or small hamlets may occur in immediate proximity to rock pile fields, and larger habitation sites (hamlets and small villages) often occur in general proximity to such fields.

Rock piles are also frequently associated with isolated artifacts or artifact scatters. Often found at rock pile sites are tabular stone tools, also referred to as agave or mescal knives, which were apparently used to cut agave leaves from the hearts (Castetter, Bell, and Grove 1938: Figure 3.5). Also found are steep-edge core tools believed to have been used as scrapers or pulping planes for the removal of fiber from agave leaves (e.g., Hester and Heizer 1972; Rogers 1939) or the precautionary removal of spines from agave leaves (Fish, Fish, and Madsen, eds. 1992; Parsons and Parsons 1990). Bernard-Shaw (1990b) has observed microscopic calcium oxalate crystals like those found in agave on tabular knife and scraper plane edges. A rather eccentric artifact type also occasionally recovered from rock pile sites is a broad ground stone implement in the form of a broad "T" (Debowski, Goddard, and Mullon 1976; Fish, Fish, and Madsen, eds. 1992). These objects are likely associated with agave processing, although a ceremonial function has also been suggested (Ferg 1986).

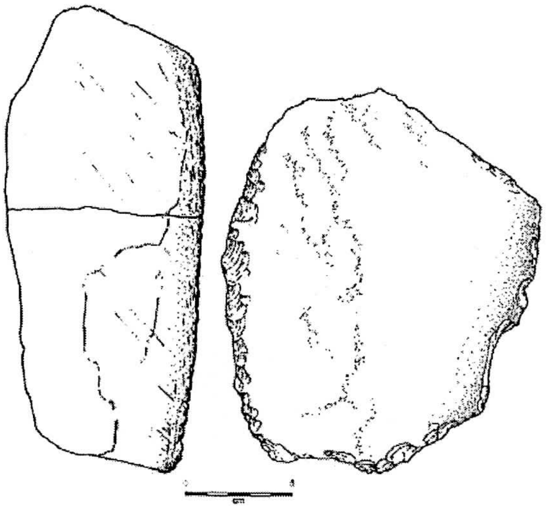

Figure 3.5. Tabular or agave knifes (adapted from Vanderpot 1992).

Relict colonies of *Agave murpheyi* are sometimes found in association with rock pile fields. Homburg (1997) notes that such colonies of agave can be seen as living archaeological features and that their presence can be seen as direct evidence that agave was farmed. *A. murpheyi* reproduces only vegetatively, either by clonal offshoots or from bulbils that fall from the stalk, and they cannot expand into new areas without human intervention (Homburg 1997; Hodgson, Nabhan, and Ecker 1989; Nabhan 1989). Confirming the presence of agave in rock piles, and at agricultural sites in general, is extremely difficult. Agave pollen is rarely identified in archaeological context (Fish, Fish, and Madsen, eds.1992;

Homburg 1997). Agave is an insect-pollinated plant and a low pollen producer. This characteristic, combined with the fact that agricultural fields are open and exposed to the elements, does not facilitate the preservation of agave pollen. The presence and use of agave is most commonly identified through the analysis of macrobotanical samples from archaeological features such as hearths and roasting pits.

Check Dams

Check dams are a feature recorded in the archaeological record of the basin-range country of central and southern Arizona as well as the uplands of eastern and northern Arizona. Check dams, as Vivian (1974:97) notes, have also been referred to as trinchera fields, trinchera plots, and terraces, and as he further notes, distinguishing between check dams and contour terraces is sometimes difficult. These features range from a single row of cobbles or small boulders arranged across a drainage to features that are several courses high and wide. Most often, check dams appear as low, rough stone walls built across small intermittent drainages, usually in narrow channels such as ravines and washes (Figures 3.6 and 3.7). It is also common to see several check dams built in the same drainage forming a step-like area. The function of the check dam is to capture sediments being transported by runoff so that an alluvium rich agricultural plot forms behind the check dam. The presence of the dam also serves to slow runoff allowing moisture to penetrate the soil behind the dam. Other investigators (e.g., Doolittle 1985; Phillips 1998:38) observe that check dams served other functions and that understanding their locations is critical to interpreting their function. As Phillips notes, check dams could be placed in eroding channels to slow, stop, or prevent incision, or they could be used to help control flooding, thus protecting crops downstream. Furthermore, it has been suggested that check dams are often located to maximize exposure to solar radiation and facilitate plant growth (Mobley-Tanaka and Eddy 1995).

Masse (1979:168-169) reports the presence of check dams in the vicinity of Tumamoc Hill in Tucson, and Fish, Fish, and Madsen (1992) note their presence, including earthen examples, in the Marana area. Most of the check dams in the Tumamoc Hill area were small, less than 5 to 6 m in length and 75 cm wide. Spacing between the features varied but averaged 4 to 5 m (Masse 1979:169).

Woodbury's (1961a) classic study of prehistoric agriculture in the Point of Pines region of east-central Arizona illustrates an extensive series of check dams, which he called terraces. One of the most extensive series was at Arizona W:10:113, where nearly 200 dams were recorded. These features ranged in length from 10 to 25 m with an average of about 20 m; wall height averaged 33 to 67 cm. The check dams occurred in three drainages and covered areas ranging in length from 260 to 280 m on slopes of 12.5 percent to 20.8 percent. The average distance between features ranged from 4.6 to 5.6 m. Another site reported by Woodbury, Arizona W:10:114, made extensive use of both check dams and contour terraces (linear borders; Figure 3.8). Up to 57 check dams occurred in a single series.

The Chevelon area also is reported to contain check dams, some of which appear to be associated with field houses (Slatter, Plog, and Plog 1976). Tuggle, Reid, and Cole (1984) report the presence of check dams, along with contour terraces, in the Grasshopper region. These dams occur singly and in sets of 3 to 13, and they range from 3 to 12 m in length. No other diversion features or field houses were associated with the Grasshopper check dams. Tuggle, Reid, and Cole note that the agricultural systems in the Grasshopper area are far less extensive than those found in the Point of Pines area and that there is little evidence of even the simplest form of water diversion or irrigation.

Neely (1995; Neely and Rinker 1997) reports on a series of water-management features in the vicinity of Pima in the Safford Valley. Some of the terracing described in associated with a large canal in what is being called System 4–AZ CC:1:36(ASM). The canal is approximately 4,630 m long, and the central portion contains several stone walls that "block the course of the drainage" (Neely 1995:23). He further notes that several of the better-preserved features have relatively large terraces behind them.

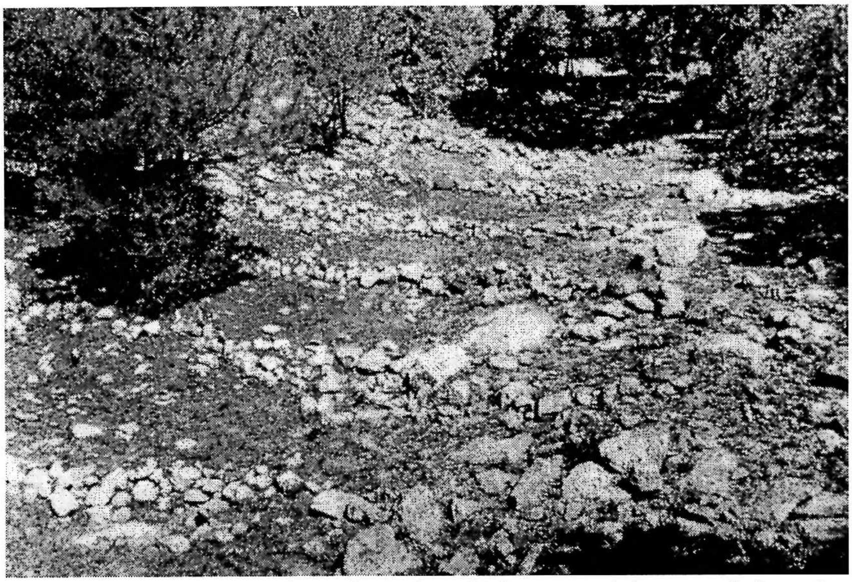

Figure 3.6. Check dams from the Point of Pines area (photograph from the files of Richard Woodbury, courtesy of Paul Fish).

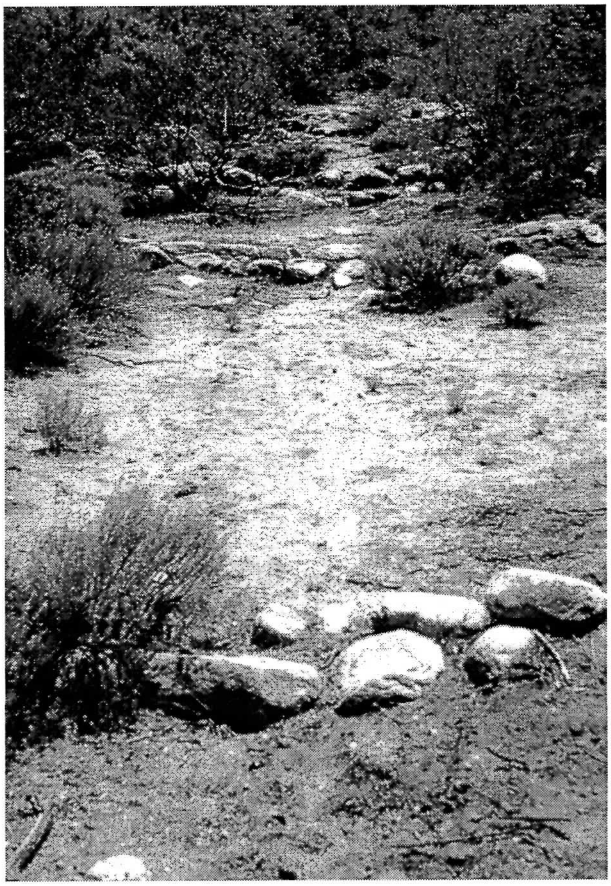

Figure 3.7. Check dams in the Goat Hill, Safford Valley area (photograph courtesy of Paul and Suzanne Fish).

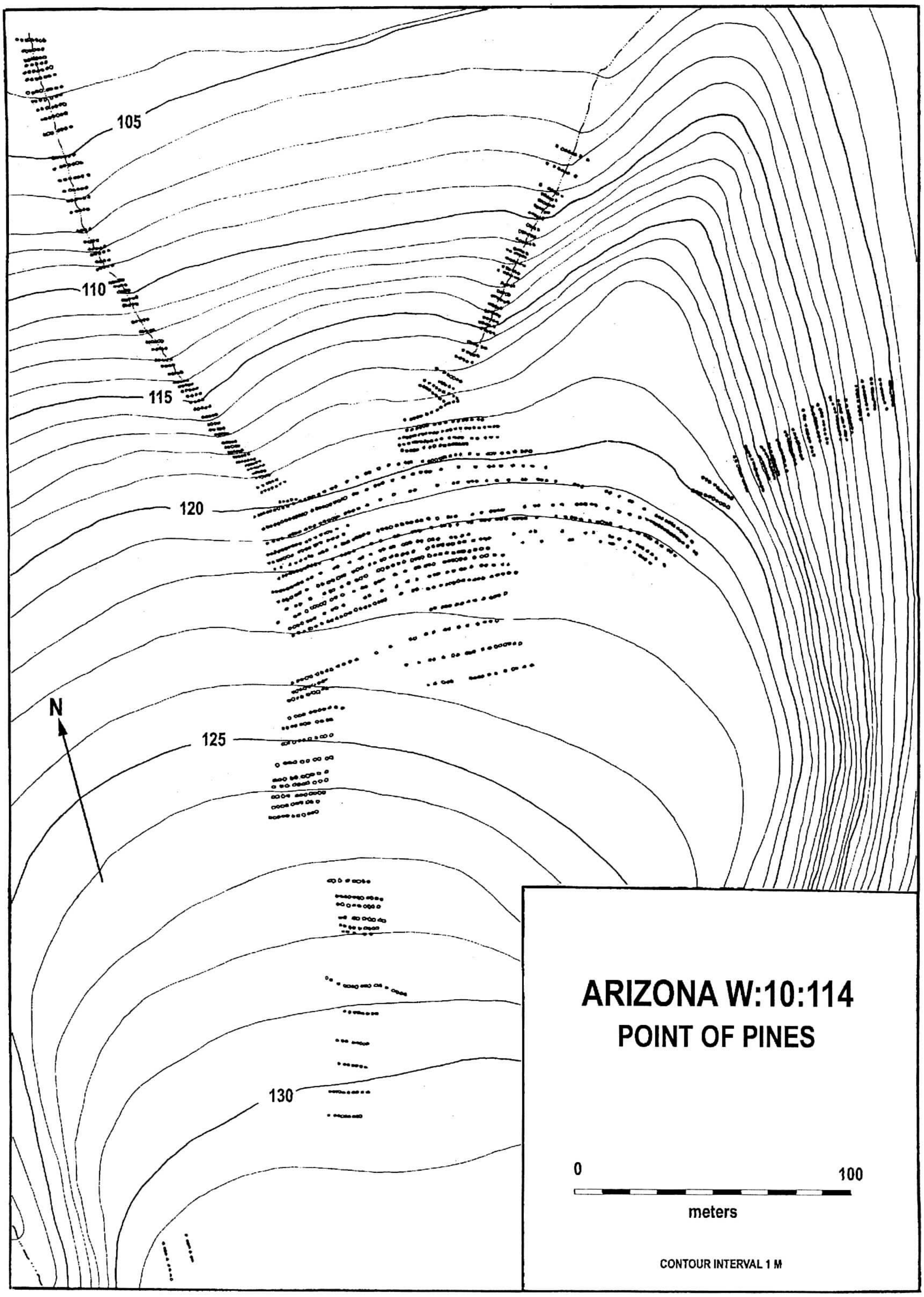

Figure 3.8. Map of Arizona W:10:114 at Point of Pines showing check dams and contour terraces (after Woodbury 1961a).

These features, which Neely variously refers to as rock walls and terraces, appear (as illustrated in Neely 1995:Figure 16) very similar in form and function to check dams, and are part of a larger system that appears to have diverted and collected rainfall and runoff.

Woosley (1980:329–332) is critical of many of the basic assumptions regarding check dams as soil or water retention devices. She observed, during a heavy rainstorm, that prehistoric check dams did little to capture water; rather, plunge pools were formed in front of the dams as water flowed over them. The pools of water that collected lasted nine days. Such pools could have supplied temporary domestic water or water for pot irrigation. Woosley also notes that plants behind the dams stand a very good chance of being washed away during heavy downpours, especially where channels are narrow and water volume is high.

Cultural and Spatial Distribution

Not surprisingly, check dams are often found in areas with steep, narrow drainages, especially in the upland zones of Arizona. These dams are typically substantial features several courses high and several course wide. However, in the lowlands check dams may be placed across broader drainages and may consist of nothing more a single course of stones. Check dams are associated with the Hohokam, Prehistoric Puebloan, and Mogollon groups of Arizona; although the larger, more substantial types have a much wider distribution in Prehistoric Puebloan contexts.

Check dams have been reported in areas such as Shinumo Canyon on the north rim of the Grand Canyon (Schwartz 1960); in the Flagstaff area (Colton 1932:16); in the Superstition Mountains (Halseth 1932); in the Homolovi area (Lange 1998); and in the Safford area (Neely 1995; Neely and Rinker 1997; also noted in field notes by Haury and Woodbury). In a survey of Homolovi State Park, Lange (1998) identified three agricultural sites with check dams, gridded or bordered fields, terraces, and canals (ditches?). A number of agricultural sites along the so-called Hohokam northern periphery (Cave Creek, New River) are reported to have check dams (Henderson and Rodgers 1979; Madsen 1981; Phillips 1998), and Crown (1984b) reports check dams 3 to 5 m long on the south terrace of the Gila River. Many times, the check dams described in the Hohokam area are not as elaborate as those found in the Prehistoric Puebloan area, frequently consisting of nothing more than a single course of small to medium-size cobbles or small boulders placed across a drainage.

Temporal Distribution

Check dams appear to date between A.D. 900 and 1400. In the Point of Pines area the earliest ones are thought to date around A.D. 1000, and they were probably most extensively used between A.D. 1300 and the mid 1400s. The systems identified by Neely in the Safford area are thought to date between A.D. 900 and 1400, based on the types of ceramics present in the fields and the occupational history of nearby sites. A similar time range appears acceptable for the Hohokam area.

Associated Features

Check dams often occur in a series in drainages and may or may not be associated with other features. Among the features more commonly associated with check dams are contour terraces (Woodbury 1961a) and sometimes field houses. Check dams are commonly found in areas that contain other water-management features, such as terracing and bordered gardens. No specific artifact assemblage appears to be associated with check dams, although artifact scatters are commonly reported, especially where the dams are in proximity to habitation sites.

Terracing

The prehistoric inhabitants of Arizona employed a variety of techniques that can generally be referred to as terracing or the use of stone alignments to deflect, redirect, and retain rainfall runoff. Terrace construction differed, depending on location and purpose. Terracing associated with prehistoric agriculture is generally less massive than that associated with architecture. Agricultural terraces may be nothing more than a simple row of stones extending a few meters or may be structures several courses high and wide running for several hundred meters. Identified types, for the purposes of this discussion, include contour terraces, bordered terraces, and revetment terraces. The reader is directed to Donkin (1979) for a useful, although it is a bit dated, comparative study of agricultural terracing in the aboriginal New World.

Contour Terraces

Contour terraces are long low stone alignments built to retain soil and capture slope runoff (Vivian 1974:97). Vivian also notes that they are sometimes referred to as "linear borders," "boulder bench terraces," and simply "terraces." Although their purpose is similar to that of check dams, contour terraces are built across hillsides or talus slopes or around knolls rather than in ravines or narrow drainages (Figures 3.9 and 3.10). It is important to note that contour terraces, unlike architectural terraces or trincheras, do not normally result in major modification of a hillslope's profile but create only a slight break in the natural profile of a hillside (Vivian 1974:97; see also Woodbury 1961a:12). Contour terraces, like rock piles, are also common features on the prehistoric landscape of central and southern Arizona.

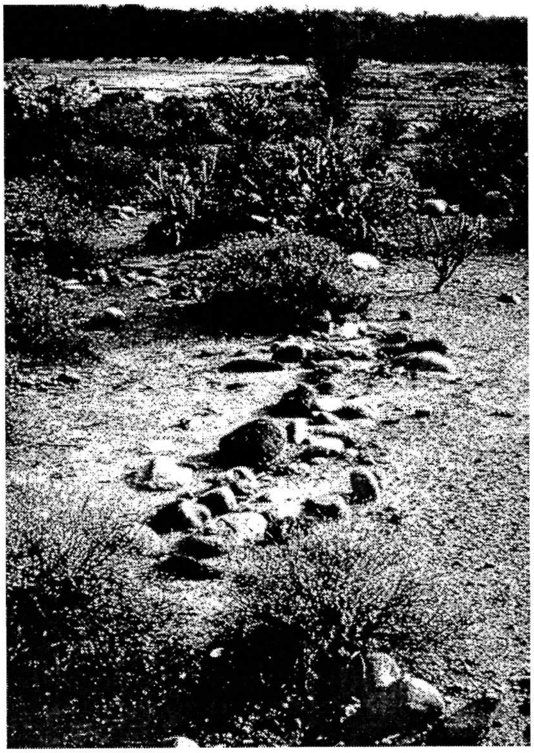

Figure 3.9. Contour terracing in the Lake Pleasant area (photograph courtesy of Paul and Suzanne Fish).

Figure 3.10. Terraces at the Pima Gridded Gardens fields, Safford Valley (photograph courtesy of M. Kyle Woodson).

Isolated contour terraces do occur, but commonly they are arranged in parallel rows that ascend a hillslope (Masse 1979), and it is not uncommon to find them scattered at different elevations across the slope of a hill. At Tumamoc Hill, 30 such features made up one of the more extensively terraced areas found there. The maximum length recorded exceeded 150 m, although most were less than 75 m long. These features were generally 3 to 4 stones (75 cm) wide; one terrace was 80 m long, 4 m wide, and several stones high, creating a level area 5 to 7 m wide on a slope of around 11 degrees. The slopes on which contour terraces occur range from about 6 to 12 degrees (Masse 1979). It is also possible that brush was used in combination with rock alignments (Doolittle 1984; Rankin 1989). Boughs would be placed in appropriate locations and held in place with rocks to slow water flow and facilitate infiltration (Phillips 1998).

Lindauer (1986) describes a series of features investigated as part of a FLEX land exchange south-southwest of Shoofly Village in the Payson area. Despite his classification of these features as check dams, they are probably better thought of as contour terracing, in that they are aligned with the contours of the slope on which they occur and were not placed in drainages or small arroyos. These features are described as constructed of dry-laid cobble-size granite and basalt rocks, two stones wide and one to three courses high. The larger stones serve as foundation stones, with the smaller stones placed to close spaces through which runoff and sediments might escape. The features range in length from 2 to 7 m. Approximately 12 to 16 cm of silty soil had accumulated behind the features.

Henderson and Rodgers (1979) report an interesting system at site AZ T:8:96(ASU) in the Cave Creek area, where contour terraces associated with a canal appear to have acted to retain waters dispersed from the canal. These terraces probably acted to divert runoff to other portions of the field. Mitchell (1998) describes several sites in the foothills of north Scottsdale that have an extensive series of contour terraces. Of particular note is AZ U:1:168(ASM) (Figure 3.11). Pollen samples were taken from several at the site. Maize pollen was present in both deep and shallow samples from Terraces 3, 6, and

15, with the highest concentrations present in the shallow samples (Smith 1998:65). Maize pollen was also recovered from a nearby midden sample. Additionally, agave, large grass (little barley or panic grass), and the lily family were represented. The overall results from AZ U:1:168(ASM) indicate that cholla, prickly pear, other cacti, large grass, and perhaps some member of the lily family were present as cultivated, tended, or encouraged crops. Smith states that agave and maize are present as definite cultigens. Overall, the northern Scottsdale sites produced a variety of cultivated and possibly encouraged native plant remains from the prehistoric fields and features investigated.

Fish, Fish, and Downum (1984) report on a variety of agricultural terraces at Los Morteros. They suggest that terracing in the Tucson Basin was used to help compensate for the unpredictability of floodwater and irrigation farming. Tuggle, Reid, and Cole (1984) report the contour terraces in the Grasshopper region in length from 5 to 180 m.

Bordered Terraces

Bordered terraces are long rock alignments bordering the edges of terraces, placed to catch and divert runoff and soil before it spills off the terraces. However, this specific feature type is not commonly described, and the term is thus not frequently applied in the archaeological literature of Arizona and may in fact be confused with bordered gardens or channeling borders.

Revetment Terraces

Revetment terraces are thought of as variations of contour terraces, differing from contour terraces by being much wider and perhaps not as long. Masse (1991a:210) suggests, that like check dams and contour terraces, revetment terraces may have served to trap soil and moisture within garden plots. However, this term is not commonly used in the archaeological literature of Arizona, except in the Tucson Basin area, and its use in the context of prehistoric water management is generally inconsistent and extremely ambiguous (e.g., Heuett 2000).

By definition, a revetment is a retaining wall: a facing of stone or other material put in place to protect a wall or bank of earth. Thus, if the term has to be used in the context of this discussion, it may be applied to an erosion-control feature. However, features described as revetment terraces are more easily and less ambiguously referred to as contour terraces if they occur on hillslopes or as check dams if they occur in some type of drainage. This may be a case of splitting versus lumping, and if one chooses to call a feature a revetment terrace, he or she should be very explicit about what the feature is and how it differs morphologically and functionally from contour terraces and check dams.

Clearly, such a feature could have been used to prevent the erosion of agricultural land, but its function should not be equated with that of a check dam or contour terracing which are put in place to control water flow. In other words, revetment terraces, as defined here, should not be likened to or associated with non-irrigation agricultural features.

Cultural and Spatial Distribution

Terracing is found in Hohokam, Prehistoric Puebloan, and Mogollon contexts. Ravesloot (1984) describes of contour terraces at AZ T:4:54(ASM) near the community of New River. The Salt-Gila Aqueduct Project recorded terraces in the Florence area, but none were found north of the Gila River (Crown 1984b). The Grasshopper area contained check dams and contour terraces, but no signs of other types of water diversion features or field houses (Tuggle, Reid, and Cole 1984). Contour terraces are also a common feature in the Point of Pines area (Woodbury 1961a). In general, terracing is widespread in much of Arizona, sharing the same general distribution as check dams and rock piles.

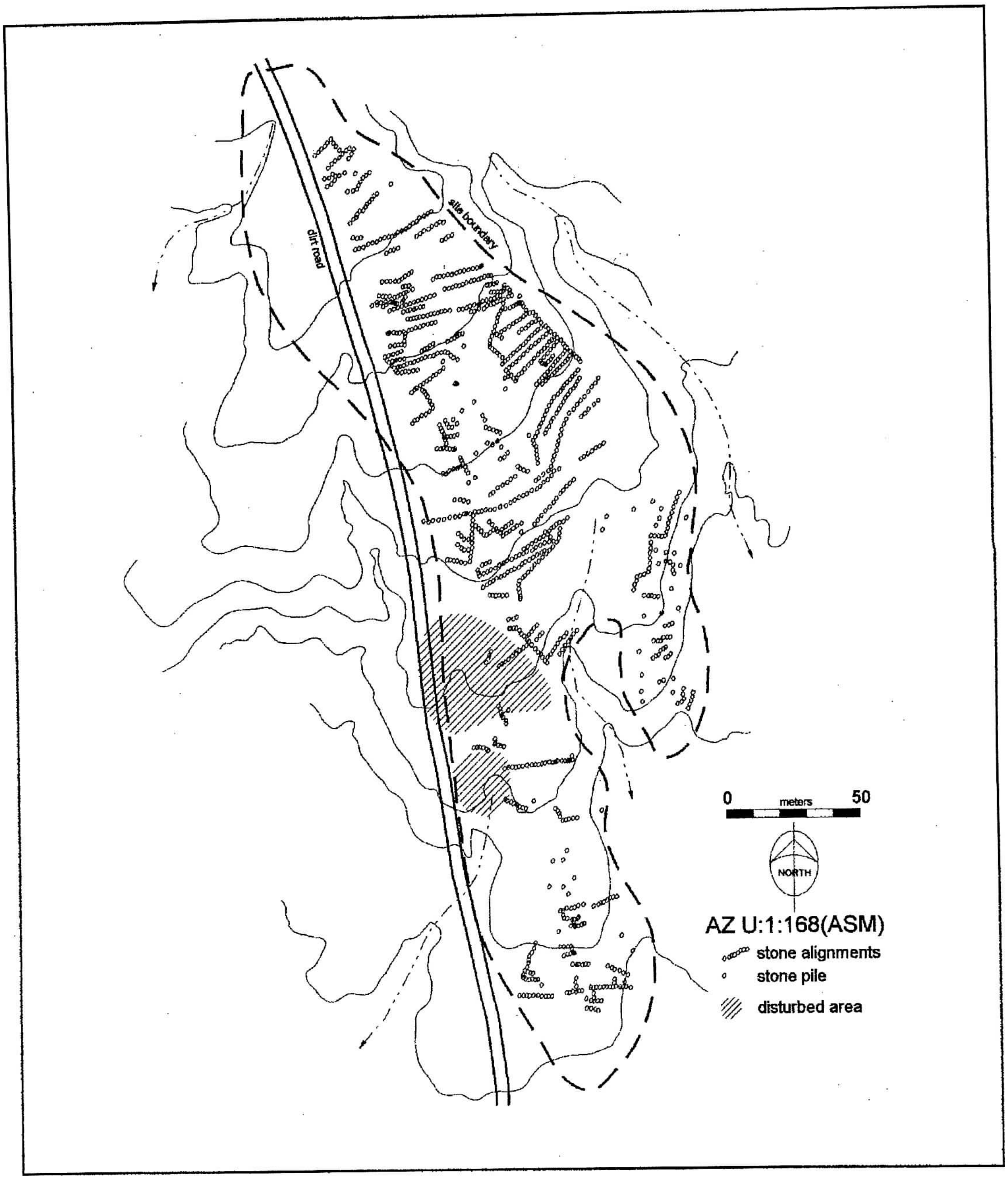

Figure 3.11. Map of AZ U:1:168(ASM) showing the extent of terracing.

Temporal Distribution

The dates for terracing parallel those suggested for check dams and other non-irrigation agricultural features. This would place them in a time range of A.D. 800/900 to 1400.

Associated Features

Check dams, rock piles (Crown 1984b; Masse 1979), and field houses (Lindauer 1986; Tuggle, Reid, and Cole 1984) are often found in association with terracing. In some areas, such as Cave Creek and Los Morteros, terraces are associated with irrigation canals (Fish, Fish, and Downum 1984; Henderson and Rodgers 1979). In many areas, they also occur in general proximity to habitation sites and likely represent associated fields or agricultural areas. No specific artifact assemblages are associated with terraces.

Borders

Borders are stone alignments that act to channel or impound runoff. Two types of borders are defined here, channeling and protective.

Channeling Borders

Masse (1979:170) defines channeling borders as stone alignments that serve to prevent sheetwash from spilling off the tops of bajadas and to channel or direct water down bajada slopes to specific field areas. Masse notes that channeling borders sometimes connect with contour terraces at the bottom of a slope.

Dove (1970) describes what seem to be channeling borders in association with bordered gardens and small rock piles in the Calderwood Butte area in the Lower Agua Fria River drainage. "Water control mechanisms were employed at one very large garden, directing hillside runoff for great distances by means of rock arranged in long rows" (Dove 1970:21).

Protective Borders

Protective borders are stone alignments placed around fields and rock pile clusters. According to Masse (1991a:210) they serve to prevent "erosive sheetflow from damaging crops planted on fields with slopes greater than about 5 degrees."

Distribution and Associated Features

The cultural, temporal, and spatial distribution of borders parallels that of contour terracing. Channeling borders sometimes connect to contour terraces, and they can be associated with other non-irrigated agricultural features such as rock piles.

Gardens

Two types of non-irrigation agricultural features have been defined. The first is the bordered or so-called "waffle" garden and the second is a similar feature called the gravel-mulched garden.

Bordered or Waffle Gardens

Bordered or waffle gardens are rectangular plots that are bordered on all sides by rocks or mounded soil. Vivian (1974) notes that these agricultural features are also referred to as terrace plots, grid gardens, garden plots, stone-outlined gardens, and grid borders. Grid border is the term Woodbury (1961b) applies to these features in the Point of Pines area. These borders serve to retain moisture and soil for crops within them (Masse 1979; Vivian 1974). The gardens vary in size and form, ranging from an individual single plot to a series of contiguous grids that are also referred to as "waffle gardens" (Masse 1991a; Woosley 1980:321 [Hopi area]). This type of garden plot is found in other portions of the Southwest as well (e.g., Kintigh 1985; Lightfoot and Eddy 1995).

Dove (1970) reported an extensive bordered garden in the Calderwood Butte area on the lower Agua Fria River. Small gardens were located on the smaller, lower river terraces while the large gardens were located on the higher, flatter terraces. Dove notes that the size of the grids varies from about I m to 20 to 30 m on a side. It appeared that the rock borders had been "raked" into place, and there were also many small piles of rock. As a result, many areas were clear of field rock, but others were not completely cleared. Dove suggests that the smaller rock left on the fields may have acted to conserve moisture in the manner of the so-called gravel-mulched gardens (discussed below).

P. Fish and S. Fish (1984) describe an extensive series of bordered gardens on Beaver Creek in the Sacred Mountain basin of central Arizona. This system was originally recorded by Schroeder (1940). The fields cover an area of about 83,000 m2 and consist of a combination of bordered gardens, terracing, and canals. Approximately 1.4 km of primary, secondary, and tertiary canals that transported water to these fields were identified. Many of the canals were excavated in fairly rocky areas, and some were apparently converted to bordered gardens (P. Fish and S. Fish 1984:Figure 4). Although no dimensions for the individual plots are provided, based on the illustrations of portions of the fields, individual grids appear to measure roughly 1.5 by 2 m in size (Figure 3.12). Crown (1984b) notes the presence of bordered gardens in the vicinity of Florence.

Neely (1995; Neely and Rinker 1997) reports a series of bordered gardens in the Safford Valley in southeastern Arizona, where bordered gardens have long been reported and are known to cover large areas (Figure 3.13). Associated with several of the garden systems are features that Neely calls "splash-pads." These are semi-circular features made from several horizontal courses of stone attached to terrace walls. Neely suggests they were put in place to prevent or reduce erosion produced by water flowing over the terrace wall.

Gravel-mulched Gardens

Gravel-mulched gardens are much like bordered gardens, but the soil in the plots is covered with small gravels to inhibit evaporation of soil moisture and perhaps, like rock piles, to help protect the roots of plants growing within them (Vivian 1974). Interestingly, in the Santa Cruz River valley, Doelle, Dart, and Wallace (1985) report numerous agricultural features in areas of moderate to heavy gravel cover. Perhaps the prevalence of non-irrigation water-management features in this area is a reflection of the fact that the gravels served as mulch that helped retain soil moisture and maximize the use of runoff. These features have also been identified in the Safford Valley.

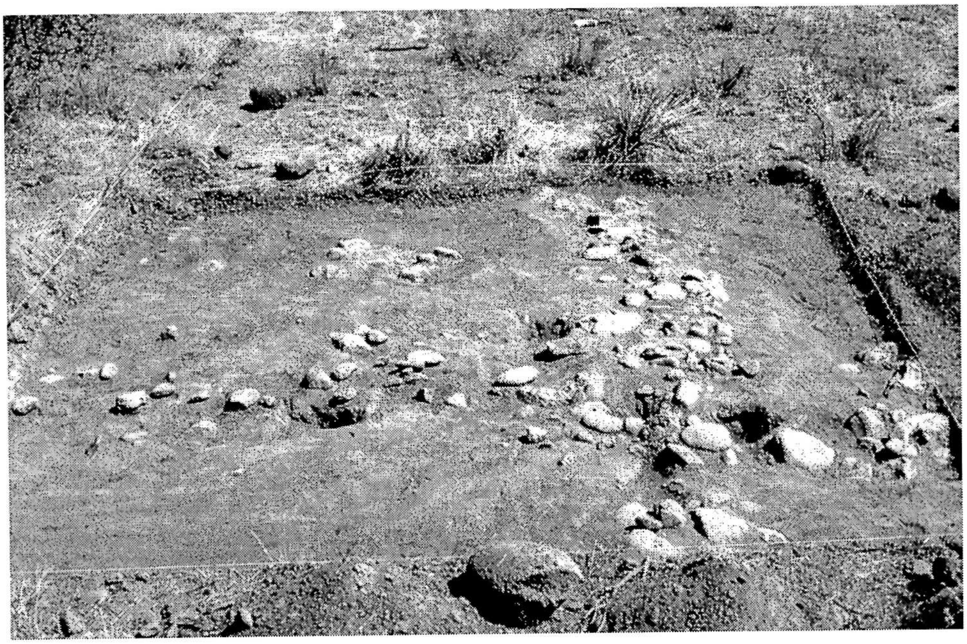

Figure 3.12. Excavated segment of a border garden at Beaver Creek (photograph courtesy of Paul and Suzanne Fish).

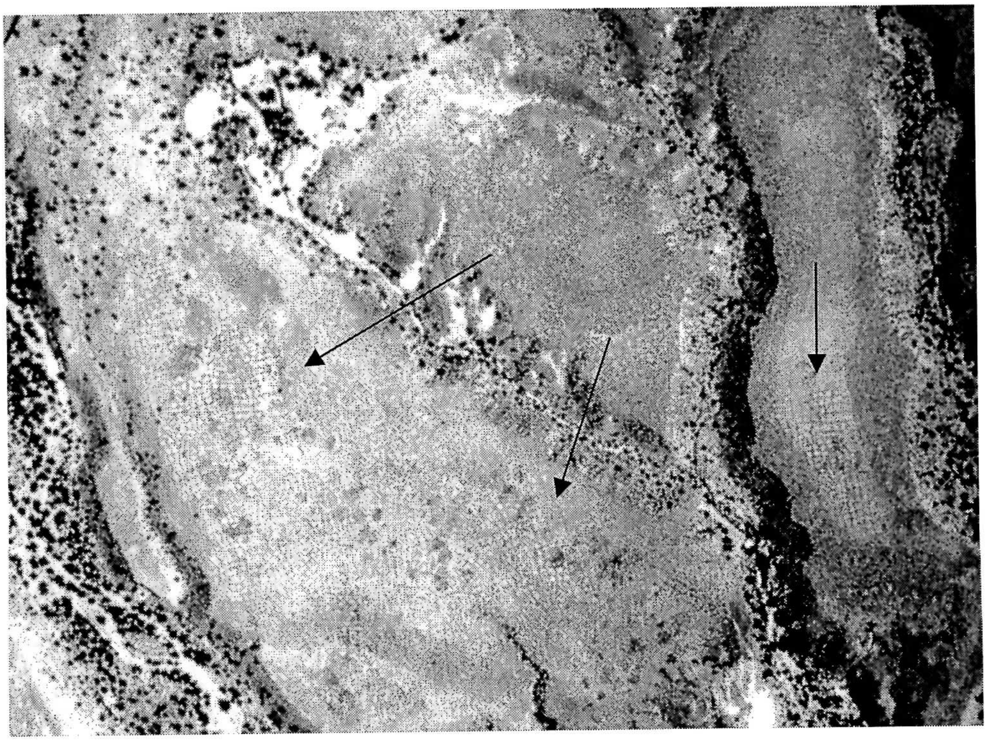

Figure 3.13. Arial photograph of border gardens in the Safford Valley (Arizona Department of Transportation photograph from the files of Paul and Suzanne Fish).

Cultural and Spatial Distribution

Bordered gardens are found in a variety of cultural settings, including the Western Prehistoric Pueblo area of northeastern Arizona, the Mogollon area of the eastern Arizona mountains, and the Hohokam are of central and southern Arizona (e.g., P. Fish and S. Fish 1984; Neely 1995; Neely and Rinker 1997; Woodbury 1961a; Woosley 1980). They were and are used by the Hopi of northern Arizona as well (Hack 1942). The walls of Hopi gardens can be quite massive and the field systems quite extensive (Figure 3.14).

Figure 3.14. Hopi border gardens near Moenkopi (photograph from the files of Richard Woodbury, courtesy of Paul Fish).

Temporal Distribution

Dove (1970) assigns the Calderwood Butte fields to the Hohokam late pre-Classic through Classic period (A.D. 950–1400). P. Fish and S. Fish (1984) indicate that the Beaver Creek systems date between A.D. 1200 and 1350. In the Safford Valley the garden systems appear to date between the mid to late A.D. 1200s and the early A.D. 1300s.

Associated Features

Woodbury (1961a) reports field houses, windbreaks, and contour terraces in association with gardens. Neely (1995; Neely and Rinker 1997) reports stone-bordered canals (channeling borders), terraces and linear borders, and splash-pads in association with gardens in the Safford Valley. P. Fish and S. Fish (1984) report canals, field houses, and field or boundary markers (elongated upright stones) with gardens in the Sacred Mountain area in central Arizona.

With the eruptions of Sunset Crater in the A.D. 1060s, an area of over 800 km2 was covered with black volcanic ash that acted as a mulch and served to conserve moisture and enhanced the land's agricultural capacities (e.g., Sullivan 1984). Fields with agricultural furrows have been identified in the area.

Fields

Many of the features discussed above occur in association with agricultural fields as constellations of a single feature type (e.g. rock pile fields) or several feature types (e.g., rock piles and contour terracing; Figure 3.15). Agricultural fields vary widely throughout Arizona, exhibiting a variety of sizes, locations, and features. The main differences among field types are based on agricultural strategy. Within those broad categories, they can be further broken down based on location and associated features. Most field types are difficult to study archaeologically because they do not involve the use of rock features or ditches that would stand up over time. Therefore, the best understood prehistoric field types are those relating to dry farming. Furthermore, as Fish (1995) notes, prehistoric and historic households living in arid environments rarely utilized a single water-management technique; rather, they tended to participate in multiple collective strategies.

Dry-farming field types are quite varied. Rock pile fields are found throughout the state and are particularly extensive along the Salt and Gila Rivers and in southeastern Arizona. Check dam fields tend to lie within drainage systems, as well as in basins, mesas, and mountains throughout the state (Buskirk 1986; Macnider and Effland 1989; Masse 1991a; Travis 1990; Woodbury 1961a). Terrace fields are also found throughout the entire state, while bordered fields and garden fields (composed of individual bordered gardens with or without gravel mulch) are more common in the northern and central portions of Arizona (Fish, Fish, and Downum 1984; Masse 1991a; Travis 1990; Tuggle et al. 1984; Vivian 1974). A rare field type, the cinder berm field, is documented only in the Sunset Crater area of northern Arizona (Berlin et al. 1977; Berlin, Salas, and Geib 1990). These gridded fields provided protection to the plants from erosional dangers in a rather open, high-wind area (Travis 1990). Finally, composite fields are probably the most common dry farming field type, as they incorporate a variety of dry-farming features (Travis 1990; Vivian 1974; Woodbury 1961a).

The concept of composite fields is important to a discussion of prehistoric agriculture because, more often than not, agriculturalists incorporated multiple types of features as a part of their strategy in order to reduce risk, increase output, deal with topographic changes, and cope with unforeseen climatological events. It has also been suggested that not such a strong dichotomy be made between irrigation and non-irrigation practices, as the two practices did sometimes overlap and augment each other (Fish 1995; Fish and Nabhan 1991).

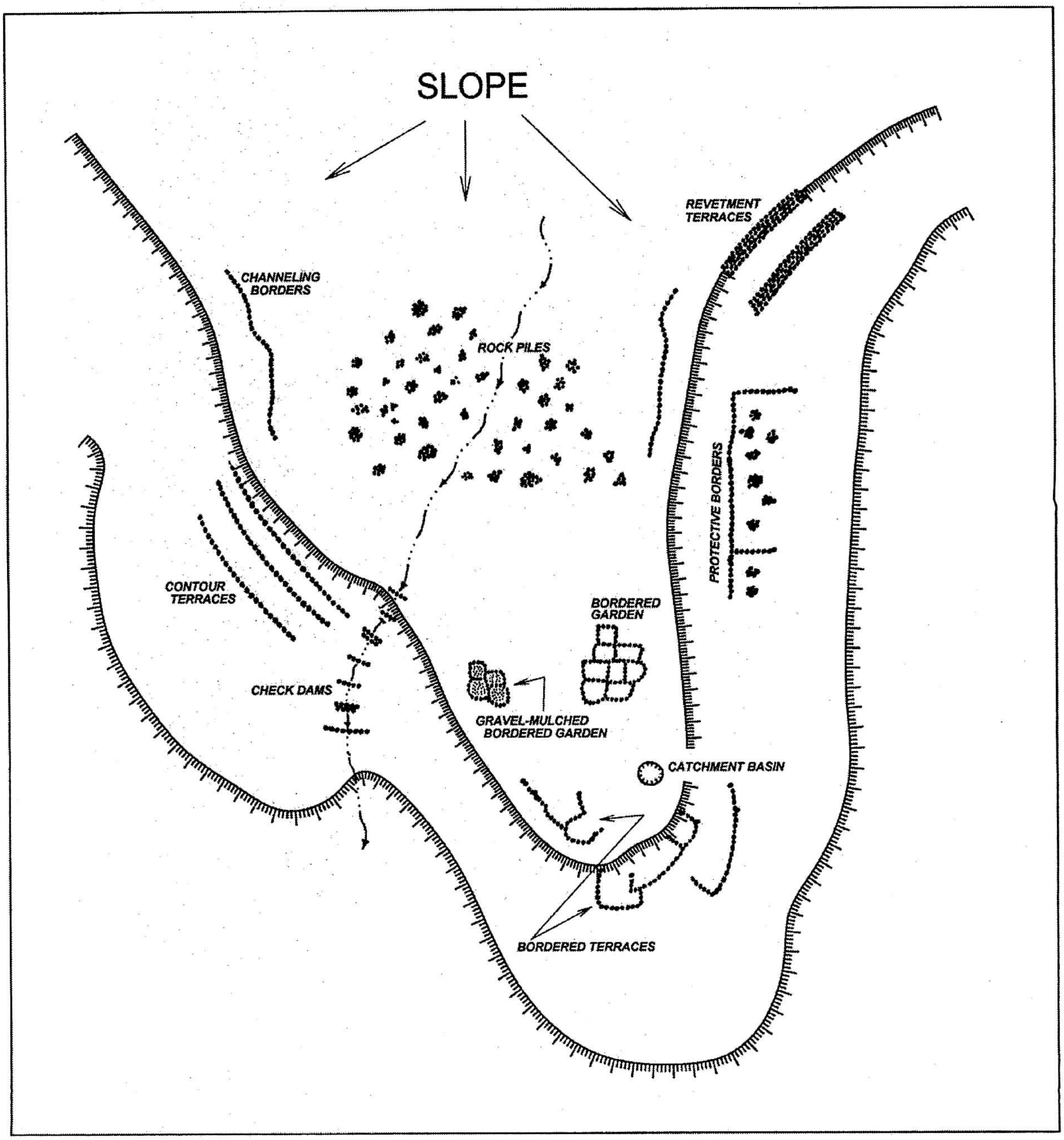

Figure 3.15. Schematic representation of various non-irrigation water-management features (after Masse 1991b, courtesy of Soil Systems, Inc).

Other property types in this category include floodwater, floodplain inundation, and runoff agriculture field (see Chapter 4). These fields are located within floodplains and alluvial fans (floodplain inundation fields), within arroyos or wash outlets, or along flat terraces and bajadas (runoff fields). Other field types include seepage and spring fields, which obtain moisture from seeps and springs, usually located uphill from the fields, and water table fields, which lie at slightly lower elevations where water is not far beneath the surface (usually close to a lake, stream or river; Glassow 1980).

Less conventional field types used in non-irrigation agriculture are also reported in the archaeological literature of Arizona. Not only are these uncommon, but the appear to be restricted to specific geographical areas. One such non-irrigated farming technique is sand dune farming which has been described in the Dead Valley in east-central Arizona (Doyel 1981). Sand dune farming relies on direct rainfall and, to a lesser extent, runoff. A number of small pueblo sites have been found in this area, all dating between A.D. 900 and 1150. It has been determined that environmental factors allowed for agriculture in the otherwise dry valley for this 250-year span. No habitation sites were found in the valley, suggesting that prehistoric peoples traveled quite far to cultivate crops but never settled there. The dunes served as the agricultural feature, with wind blocks in front of them as shields from harsh winter conditions. It is thought that the region was no longer used for cultivation after such a relatively short time span because, unlike in floodwater agriculture, the soil nutrients in sand dunes are not renewed and productivity decreases rapidly (Doyel 1981:151).

The Hopi Indians of northern Arizona have long used sand dune farming (Figure 3.16), as well as almost every other technique discussed in this chapter (Hack 1942). Undoubtedly, this technique was used prehistorically throughout the upland areas of Arizona, as well as anywhere else it could be applied.

Another unusual non-irrigation farming technique, burn-plot farming, has been described for the Sunset Crater area (Sullivan 1984). This strategy involves burning the ground litter in pine forests, thus clearing the ground for the planting of garden plots and small fields. Such plots would depend mainly on direct rainfall for moisture.

Cultural and Spatial Distribution

The cultural and spatial distribution of fields across Arizona obviously parallels the distribution of prehistoric agriculturalists within the state. One issue affecting the spatial distribution of fields is scale. Fields are by definition larger than household garden plots. Beyond that, prehistoric fields varied in size, probably from just large enough to support or partially support households, to areas capable of providing cultigens for population segments of villages. Fields have been identified in the Prehistoric Pueblo, Mogollon, Sinagua, and Hohokam (Salado) areas.

Temporal Distribution

It is likely that fields of some size appeared with the introduction of cultigens during the Early Agricultural period (200 B.C.–A.D. 1/150). These fields were likely small plots that were watered by rainfall or overflowing floodwaters. With the establishment of agriculture as way of life, in the A.D. 500s to 700s, fields became a part of the cultural landscape.

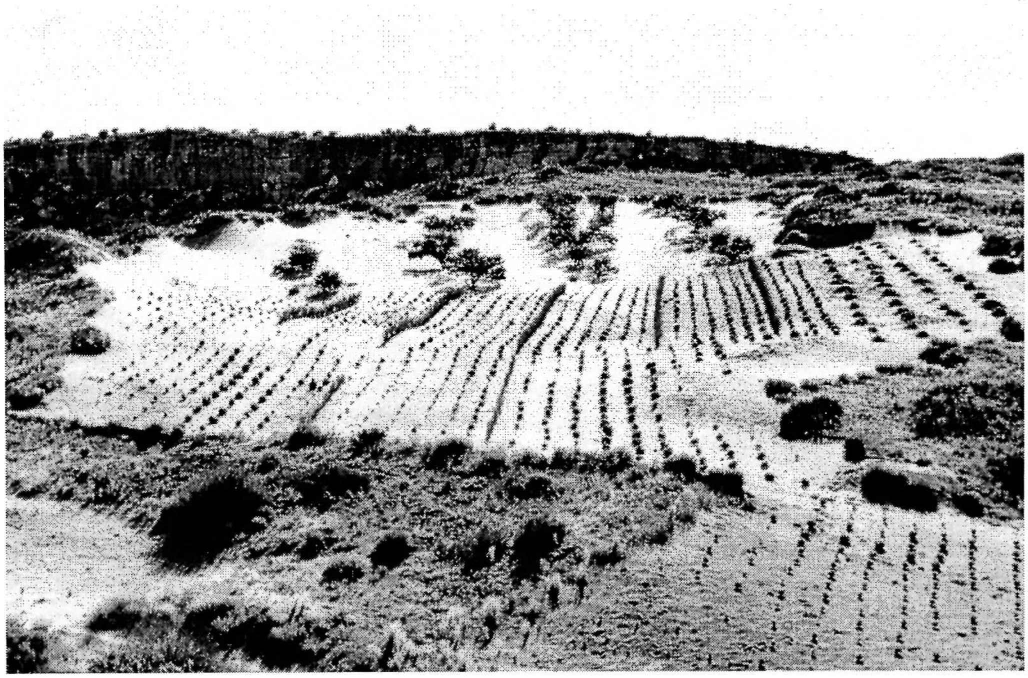

Figure 3.16. Hopi sand dune fields. Note brush windbreaks between rows (compare Hack 1942:Plates Vc and Via; photograph courtesy of Michael S. Foster).

Associated Features

Agricultural fields have been documented in association with other feature or site types that served as habitation or shelter for those tending the fields. These sites vary widely, from small ephemeral structures, to large villages. The type of associated site depended on the culture's settlement type, population size, permanence of occupation, and range of functions (Gregory 1991).

The largest, least-specialized sites affiliated with agricultural practices are habitation sites. These are villages and hamlets representing aggregation of larger populations (i.e., more than a single group) and they served more than agricultural purposes. A hamlets is defined as consisting of several small structures and as having fewer than 100 people; a village has more structures and more than 100 people. Both of these site types were occupied year-round and served long-term purposes. Often times, occupants of habitation sites would use smaller sites for temporary residency while planting, tending, or harvesting crops (Gregory 1991).

Farmsteads are small settlements, thought to have been occupied seasonally, that were established solely for the agricultural pursuits of a single group. It is thought that these sites were extensions of larger villages/hamlets with which they maintained continuing ties (Gregory 1991). Farmsteads are usually composed of one or two jacal-lined pit houses, usually with interior hearths (Doyel 1984).

The smallest, most functionally limited structure is the field house. This feature was an individual, single-room structure, constructed of stacked cobble masonry with a probable brush roof or superstructure, established for the single purpose of tending fields (Doyel 1984; Gregory 1991). There usually are no interior features. These types of structures usually occur some distance away from the habitation area, in the immediate vicinity of agricultural fields. It is inferred that field houses were occupied only during brief periods of planting, growing, tending, or harvesting crops (Gregory 1991). Rock ring features found in association with agricultural field sites are often interpreted as the remains of field houses or similar types of ephemeral, solely agricultural structures.

Catchment basins are depressions, either natural and constructed, used to catch rainfall and runoff for later watering plants (pot irrigation) as well as to store water for domestic purposes (Masse 1991a; Crown 1987b; Woosley 1980). These features are most often documented at Hohokam sites (Masse 1991a; see Chapter 4).

Storage facilities are often associated with agricultural sites, either as accompaniments to field houses or within habitation sites. Pits and large ceramic vessels were used to store seeds, harvested crops, and water (Crown 1987b; Macnider and Effland 1989).

It is likely that small ramadas were constructed adjacent to fields to protect people from the sun and weather. Such structures were and are widely used in the Hopi area today (Figure 3.17). Windbreaks also provided relief in high-wind areas, particularly in the Puebloan region on the Colorado Plateau. These were shelters of brush and/or rock, with or without a roof (Mindeleff 1989). Rock semicircles documented at Puebloan sites have been interpreted as being windbreaks (Doyel 1981; Travis 1990).

Field or boundary markers have been found throughout much of Arizona in various forms, serving to designate where one field ended and the next began (P. Fish and S. Fish 1984; Travis 1990; Woodbury 1961a).

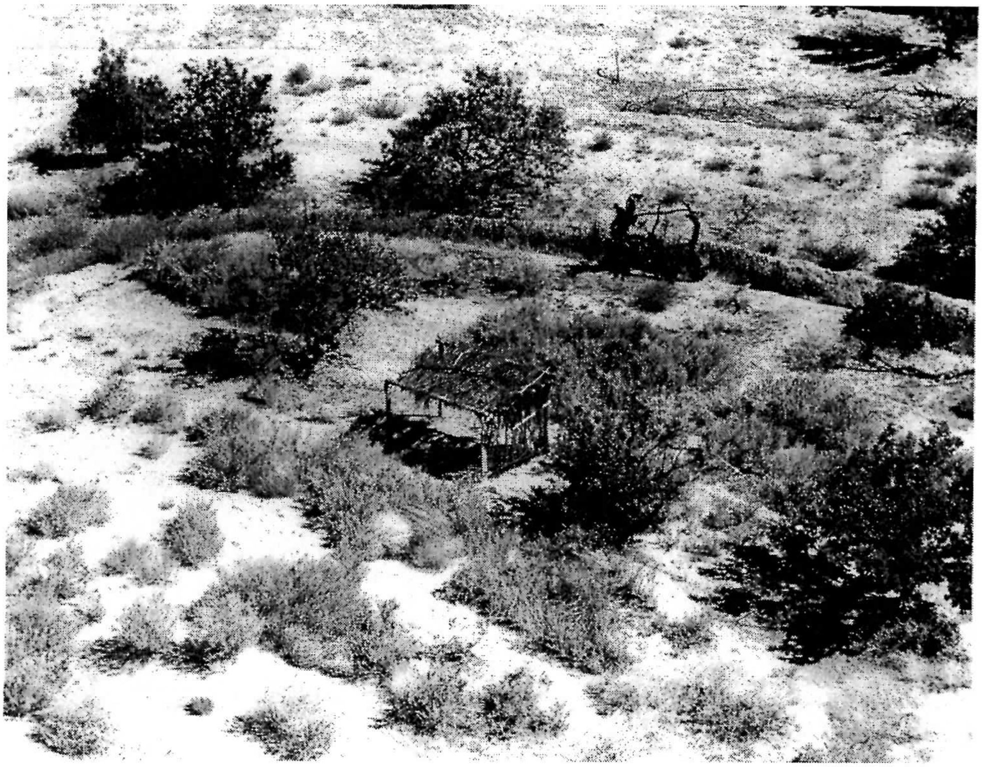

Figure 3.17. Hopi field hut or ramada (photograph from the files of Richard Woodbury, courtesy of Paul Fish).

SUMMARY

The prehistoric inhabitants of Arizona used an array of water management and conservation devices, including rock piles, terraces, check dams, and bordered fields, to provide sufficient moisture for their agricultural endeavors. These devices helped the prehistoric peoples of Arizona develop a sedentary lifeway that lasted a thousand years before, ironically, lack of rainfall and occasional catastrophic flooding in some of the region's major river systems resulted in a widespread collapse of prehistoric cultures across Arizona.

The redundancy in form and function of these features across Arizona is of note. As Doyel (1993a:39) observes, "this is expected because of the basic engineering principles involved in prehistoric agriculture." Doyel further suggests that the main differences between areas have to do with degree of dependency on agriculture, scales of systems, and local topographic and hydrological factors. For example, much of northern and eastern Arizona does not lend itself to the type of irrigation agriculture seen in the Hohokam area. Nevertheless, the Prehistoric Puebloans, the Mogollon, and the Hohokam employed many of the same techniques to capture, manipulate, and use water. Table 3.2 at the end of this chapter summarizes the non-irrigated farming techniques discussed here.

Central and Southern Arizona Deserts

Because of the low amount of precipitation, the main limiting factor for the prehistoric inhabitants of southern Arizona was undoubtedly water. As a result, the Hohokam incorporated the entire range of agricultural practices, for the most part with the exception of runoff agriculture, utilizing the numerous drainages, terraces, floodplains, and bajadas available to them. The Phoenix Basin Hohokam are famous for their extensive canal systems, while in other areas, less visible but nevertheless impressive dry-farming and floodwater systems were constructed. In addition to irrigation and non-irrigation technologies, reservoir features were sometimes used to capture rainwater for later use (Bayman 1992).

Small agriculturally related hamlets have been found throughout the state dating to the late Archaic and early Ceramic periods. Although a lack of incipient agricultural sites from the Archaic period in the Phoenix Basin region is seen by some (e.g., Cable and Doyel 1987; Doyel 1991) as evidence for regional variations in the adoption of agriculture, it is possible that such sites simply have not yet been found. Nevertheless, reliance upon sedentary agricultural practices was low during the first two or three centuries A.D., as moderate mobility was continued and smaller populations were maintained. Although Archaic groups were not sedentary, some reliance on certain cultigens is undoubted, with evidence of maize throughout the Tucson Basin dating back several thousand years.

In the Pioneer period, with the ability to support larger populations, larger, more sedentary villages became more common. These villages were supported by both irrigation and non-irrigation technologies, with most of the irrigation systems being developed in the Phoenix Basin (Wilcox and Sternberg 1983).

The huge cultural shift that occurred upon the transition to the Classic period (ca. A.D. 1150) brought with it major changes in agricultural technology throughout the entire Hohokam region. In the Phoenix Basin, the canal systems were expanded and the types of crops were diversified. Outside of that area, contour and bordered terrace systems were used more widely, and rock piles began to be used for planting crops, not just for diversion purposes (Fish, Fish, and Madsen 1992; Doyel 1991).

The post-Classic/Protohistoric Hohokam occupation is much less well understood by archaeologists, but it tends to be defined by less complex social structure and agricultural strategies. The link between the Hohokam and the ethnohistoric inhabitants of southern Arizona is not fully understood (Doyel 1991; Ezell 1963; Fish 1989).

East Central Arizona Mountains

Although water was more plentiful in this portion of Arizona, the Mogollon inhabitants of this area were limited by topographic factors such as high slopes, slope erosion, thin soil, and lack of flat land. Thus, the Mogollon became adept at ridge top and terrace dry farming practices.

Like the Tucson Basin of southern Arizona, east-central Arizona is studded with Archaic sites containing evidence of maize (Matson 1991). Later, more sedentary and archaeologically visible pit house sites appear, built into the mountains at a range of elevations (Haury 1940). Agricultural practices throughout this region tended to include a variety of dry-farming technologies including rock piles, check dams, terraces, and bordered gardens. Many of these features appear to have been constructed for soil-erosion control (Woodbury 1961; Tuggle et al. 1984).

Northern Arizona Plateau

In the northernmost portion of the state, dominated by the Colorado Plateau, water again was a limiting factor for prehistoric agriculturalists. Like the Hohokam, prehistoric Puebloans practiced a range of agricultural technologies, including all methods of floodwater farming, sand dune farming, the use of small ditches and canals, and a variety of dry-farming methods (Travis 1990; Vivian 1974). Again, dry-farming features varied regionally. Bordered (both gravel-mulched and cleared) gardens, check dams, and contour terraces have been documented in the region of the Kayenta and Upper Little Colorado Puebloans, while the Rio Grande region used mostly gravel-mulched bordered gardens (Lightfoot and Eddy 1995; Snow 1991; Vivian 1974). In the Wupatki area, north of Flagstaff, dry-farming features included rock piles, contour terraces, check dams, bordered terraces, channeling borders, and field markers (Travis 1990). Also present in the Flagstaff/Sunset Crater area are cinder agricultural furrows. Windbreaks are also very common throughout this area (Doyel 1981; Travis 1990). An environmental and climatological reconstruction of the prehistoric Colorado Plateau, based on dendrochronological (tree ring) evidence, showed a peak in agricultural potential for a 200-year period from A.D. 900 to 1000 (Dean 1992). It was during this period that sand dune farming was occurring in the Dead Valley region (Doyel 1981).

Western Desert

Little is known regarding water management and water-management technologies of the prehistoric peoples of the western desert and Lower Colorado River valley (Stone 1986, 1987, 1991). Rock alignments that may have functioned as some form of water-control device have been reported, but it appears that most agricultural activities probably occurred in river and stream valleys. Floodwater farming was likely the primary water-management technique utilized (e.g., Castetter and Bell 1942).

Non-Irrigation Water Management Feature Settings

Non-irrigation agricultural features and fields occur in a variety of topographic settings. They are common in upper, middle, and lower bajada settings, on floodplains, and on terraces of streams and major rivers (e.g., Fish, Fish, and Madsen 1992; Homburg 1997; Masse 1979). Contour terracing and rock piles occur on fairly level plains or fluvial settings on slightly sloping terraces or on ridge tops with slopes of less than 5 degrees. They also occur on the slopes of bajada zones where the slopes range from 6 to 12 degrees. Border gardens generally occur in areas of low relief. In the Florence area they occur in areas of about 1 to 2 degrees slope (Crown 1984b).

By definition, check dams occur in drainages, and the configurations of these drainages vary greatly. In mountainous regions the drainages tend to be more steep and narrow, while in the desert regions, they are commonly found in less steep and narrow drainages as well.

Figures 3.18 through 3.20 show the distribution of various water control and soil management devices across the state. The data these maps reflect were derived from AZSite files (see Chapter 1). The shading indicates general areas containing such features at recorded sites. It is likely that survey of previously univestigated areas in these locations would result in the identification of additional water-management features and sites.

Table 3.2. Summary of Non-irrigated Agricultural Features Types, Regional Distribution, Temporal Distribution throughout Arizona.

FEATURE TYPE	CULTURAL DISTRIBUTION	TEMPORAL DISTRIBUTION	SPATIAL DISTRIBUTION	SELECTED REFERENCES
Rock pile	Tucson and Phoenix Basin Hohokam; Puebloan; Mogollon	Definitely by A.D. 900, possibly as early as A.D. 300 - continuing throughout Hohokam sequence in Tucson Basin; circa A.D. 1100 - 1250 as agricultural mounds in Tucson Basin.	Southeast; Central; Northern; Forestdale Valley	Buskirk 1986; Crown 1987a, 1991; Fish 1995; S. Fish and P. Fish 1984; Fish, Fish, and Madsen 1992, eds. 1992; Masse 1991, 1979; Travis 1990
Check dam	Tucson and Phoenix Basin Hohokam; Mogollon; Puebloan	Definitely by A.D. 900, possibly as early as A.D. 300	Southeast; Grasshopper; Central; Point of Pines; Northren; upper Little Colorado; Kayenta; Forestdale	Buskirk 1986; P. Fish and S. Fish 1984; Masse 1979, 1991a; Travis 1990; Tuggle et. al 1984; Vivian 1974; Woodbury 1961a
Contour terrace	Tucson and Phoenix Basin Hohokam; Mogollon; Puebloan	Definitely by A.D. 900, possibly as early as A.D. 300.	Southeast; Grasshopper; central; Northern; Upper Little Colorado; Kayenta	P. Fish and S. Fish 1984; Fish 1995; Masse 1979, 1991a; Travis 1990; Tuggle et. al 1984; Vivian 1974
Bordered terrace	Tucson and Phoenix Basin Hohokam; Puebloan	Definitely by A.D. 900, possibly as early as A.D. 300.	Southeast; central; Northern	P. Fish and S. Fish 1984; Masse 1991a; Travis 1990
Revetment terrace	Tucson and Phoenix Basin Hohokam	Definitely by A.D. 900, possibly as early as A.D. 300.	Southeast	Masse 1991a
Channeling border	Tucson and Phoenix Basin Hohokam; Puebloan	Definitely by A.D. 900, possibly as early as A.D. 300.	Southeast; Central; Point of Pines; Northern	P. Fish and S. Fish 1984; Masse 1979, 1991a; Travis 1990; Woodbury 1961a
Bordered garden - also called terrace plot, grid garden, garden plot, stone-outlined garden, grid border, waffle garden	Tucson and Phoenix Basin Hohokam; Puebloan	Definitely by A.D. 900, possibly as early as A.D. 300.	Southeast; Northern; Central; Upper Little Colorado; Kayenta	P. Fish and S. Fish 1984; Masse 1979, 1991a; Travis 1990; Woodbury 1961a; Vivian 1974
Gravel-mulch bordered garden	Puebloan; Western Hohokam	Definitely by A.D. 900, possibly as early as A.D. 300.	Rio Grande; Northeastern Arizona; Safford Valley	P. Fish and S. Fish 1984; Lightfoot and Eddy 1995; Masse 1991a; Vivian 1974
Protective border	Tucson and Phoenix Basin Hohokam	Definitely by A.D. 900, possibly as early as A.D. 300.	Southeast	Masse 1991a
Catchment basin / retention basin	Tucson and Phoenix Basin Hohokam	Definitely by A.D. 900, possibly as early as A.D. 300.	Southeast	Crown 1987b; Masse 1991a
Ditche	Puebloan		Upper Little Colorado; Kayenta	Vivian 1974

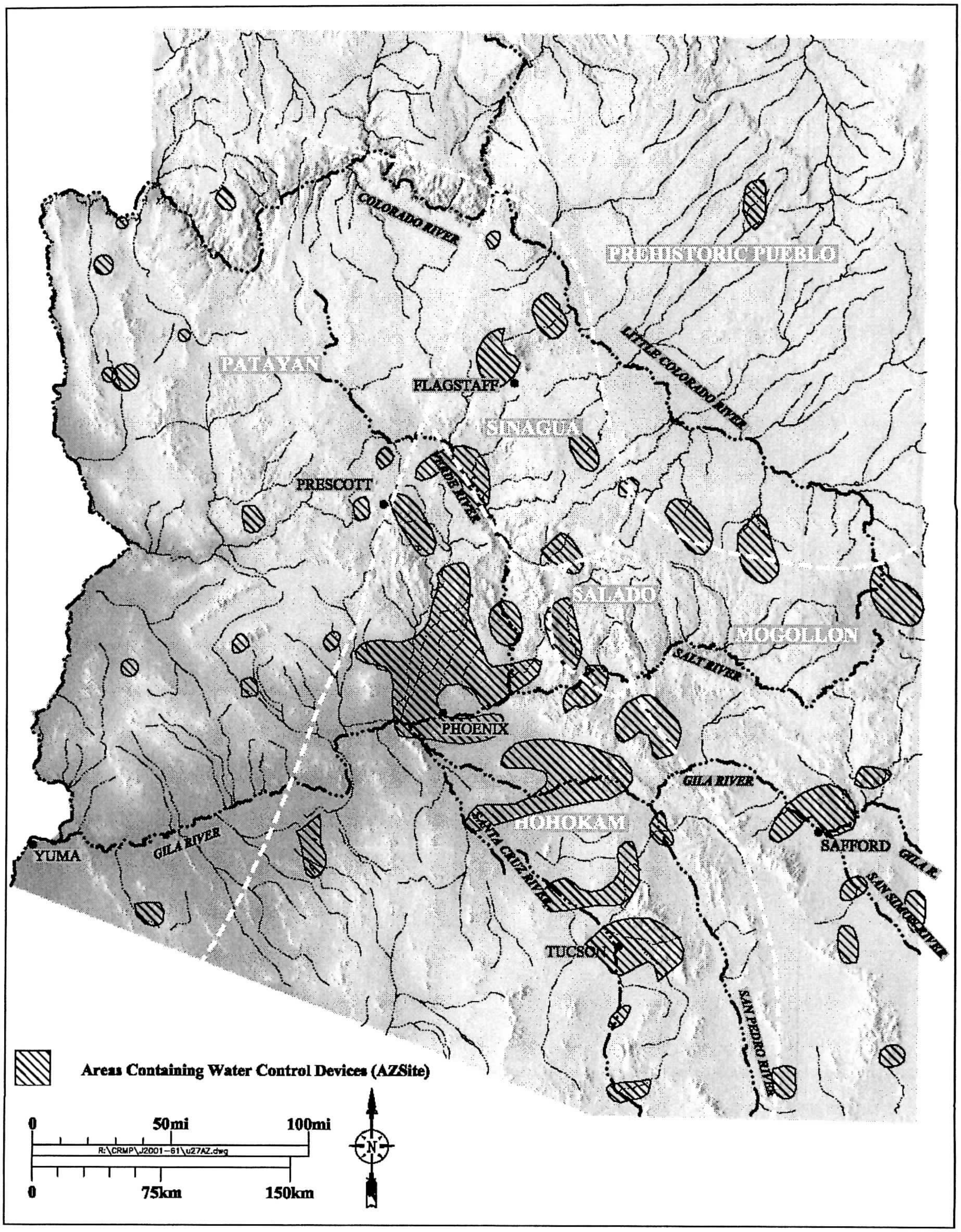

Figure 3.18. Map showing the distribution of areas containing features listed as water-control devices in the AZSite database.

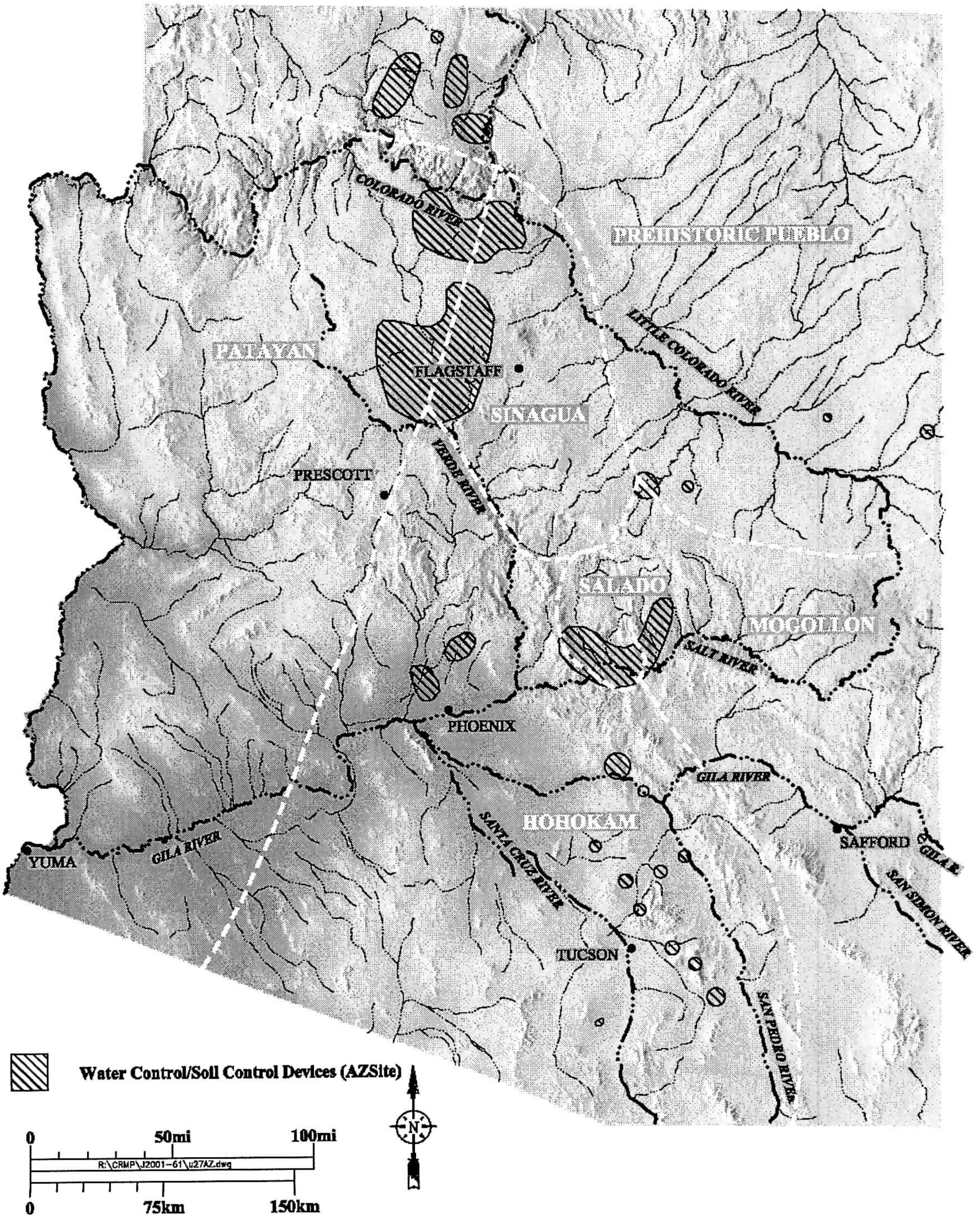

Figure 3.19. Map showing the distribution of areas containing features listed as water-control/soil-control devices in the AZSite database.

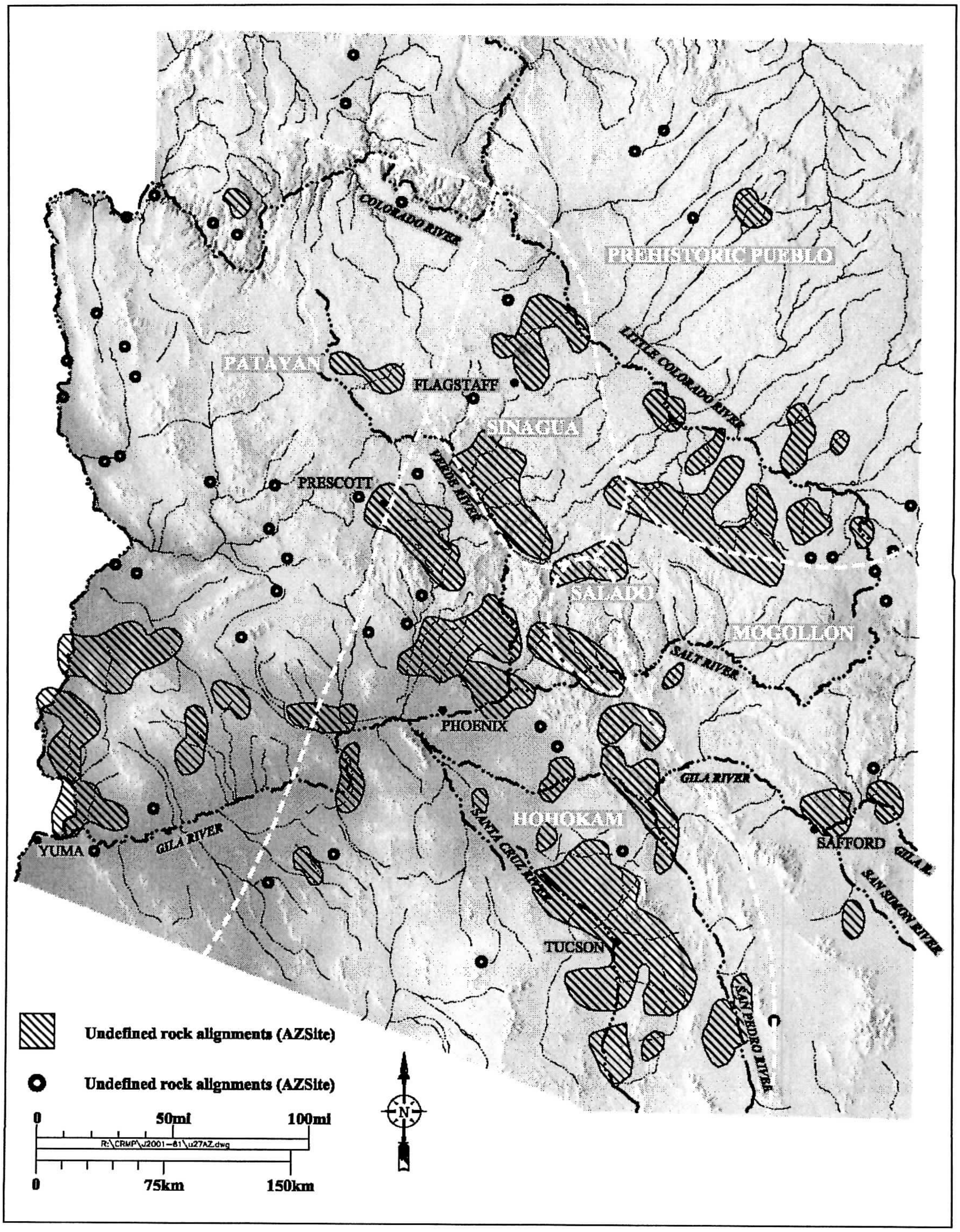

Figure 3.20. Map showing the distribution of features listed as undefined rock alignments in the AZSite database (it is likely many of these features are associated with prehistoric water management and use).

CHAPTER 4

FLOODWATER AND OTHER WATER UTILIZATION AND MANAGEMENT TECHNIQUES

Michael S. Foster

"Rain is grace; rain is the sky condescending to the earth; without rain, there would be no life."
–John Updike (1989)

This chapter focuses on two general topics not discussed elsewhere in this document: floodwater-farming techniques and a miscellany of other water-utilization techniques that are related to both domestic and agricultural uses of water. Several of the water-management techniques are not or cannot easily be identified on the ground. As noted earlier, many techniques known ethnographically leave no physical remains, and it is certain that this is the case archaeologically as well. A simple agricultural plot or cornfield in the floodplain of a stream or river may leave no discernible remains. Small ditches, earthen dams or diversion berms, or brush weirs may be washed away by flooding and not recognizable in the archaeological record. Thus, there may be no identifiable and definable property types that can evaluated in terms of eligibility for the NRHP. Nevertheless, a thorough survey of prehistoric water utilization requires that we discuss and describe techniques that were likely used or could have been used.

FLOODWATER AND RUNOFF UTILIZATION AND MANAGEMENT

Floodwater Farming

Rankin and Katzer (1989) point out that the term floodwater farming (Bryan 1929), as used by archaeologists, is frequently the subject of a great deal of confusion (Nabhan 1982, 1986a, 1986b; Nabhan and Masse 1986). The problem lies in the fact that floodwater and runoff agricultural systems are often seen as one and the fame. Floodwater systems utilize the channels of ephemeral streams and washes, large streams, and rivers. Agricultural plots are located in such channels, and they are inundated during increased or maximum flows derived from snowmelt or flooding. In flood<u>plain</u> farming, on the other hand, fields are placed on rich alluvial features within the floodplains adjacent to stream and river channels (not within the channels). These fields are also subject to inundation when the peak capacity of the channels is exceeded during flooding. The geomorphic setting of a floodplain field is argued to be the distinguishing factor between these two terms. However, the distinction is not great, and the use of one term over the other should be justified based on geomorphic and hydrological setting. Because the sources of water are the same, the overflow of seasonal (e.g., snowmelt) or flash (e.g. thunderstorms) flooding, it is suggested here that the term *floodwater farming* be applied to both situations.

Floodwater farming is a relatively simple strategy that was probably one of the first forms of agriculture practiced throughout the Southwest, and it has been widely documented in the ethnohistoric record (Castetter and Bell 1951). However, specific documentation of this practice is difficult because it does not utilize any artificial features, and does not leave much of an archaeological signature.

As discussed in Chapter 2, floodwater farming likely has a long history in Arizona and was probably widely used by the earliest agriculturalists across the state. It was certainly in use by the first century A.D., and was widely used by A.D. 900 (Doyel 1991; Masse 1991a). This technique was practiced across the Hohokam region during the Pioneer period of the Hohokam chronology, serving as the primary agricultural technology in the Phoenix Basin at that time. After A.D. 750, floodwater farming continued as one of many agricultural strategies in the Tucson Basin but was replaced by irrigation in the Snaketown phase in the Phoenix Basin (Doyel 1991).

The central and southern portions of the state were the main loci for floodwater techniques in Arizona, although historic ethnographic evidence has documented use of such strategies being carried out in the northeastern region, around the Lower Colorado River (Castetter and Bell 1942). Discussing the archaeology of the Colorado River valley, Stone (1991:66) notes that prehistoric River Patayan settlement and subsistence practices are poorly known. These groups lived in small dispersed settlements with farm plots that have probably been inundated by reservoirs, buried by silt deposition, or eroded by floods and the lateral shifting of river channels. Nevertheless, it is likely that floodwater farming played a role in the subsistence of the River Patayan (Stone 1991:61).

Because flooding often changes runoff patterns, floodwater-irrigated fields sometimes have to be moved over some distance. This makes field locations quite unstable, a problem not encountered with other agricultural practices. On the other hand, flooding brings a continuous supply of nutrient enrichment to floodplain fields, serving as a fertilizer of sorts (Masse 1991a; Nabhan 1983a).

Alluvial Fan Floodwater Farming (Ak-Chin)

Another term ambiguously tossed around in the archaeological literature of the Sonoran Desert and to a somewhat lesser extent in other parts of Arizona (e.g., Hack 1942) and the American Southwest is ak-chin (*'ak-ciñ*). It is common to see ak-chin cited as a type of farming at the mouth of an arroyo or on a delta/alluvial fan at the edge of a bajada. Nabhan (1986a) notes the term was translated to mean "mouth of a wash, the place where a wash looses itself in the sand or ground. Ak is a term for a usually dry watercourse or wash (Nabhan 1986a). As Rankin and Katzer (1989) observe, the term has become synonymous with farming at an arroyo mouth (e.g., Bryan 1929; Gasser and Kwiatkowski 1991), and as a result the term is widely misused.

Ak-chin farming is generally described as a type of floodwater farming that is dependent on rainfall runoff and water diversion. This strategy differs from floodplain inundation in that fields are located on alluvial fans at the mouths of washes or arroyos or along the edges of bajadas (Nabhan 1986a). Ak-chin farming is also thought to be more labor-intensive than floodplain inundation because small ditches and diversion features are often constructed and used to direct water toward the fields (Castetter and Bell 1951; Masse 1991a). Archaeologically, it has been argued that ak-chin agriculture allowed for relatively sizable villages to be constructed on bajada slopes away from large streams and rivers (Craig and Wallace 1987; Masse 1991a).

Among the Tohono O'odham, the term ak-chin does not refer to fields or farming techniques but rather to villages or specific locations along ephemeral watercourses at specific times (Nabhan 1986b). Essentially, what Rankin and Katzer (1989) are arguing is that use (or abuses, e.g., Doyel 1985) of the term ak-chin to describe a water utilization and farming technique is inappropriate, if not incorrect. They suggest that the term alluvial fan floodwater system is more accurate and descriptive. In general, it appears that the chances of the term ak-chin being misapplied in an archaeological context are significant enough to warrant abandoning its use. Therefore, it is recommended that the Rankin and Katzer term, *alluvial fan floodwater system*, be used instead. Archaeologists who feel compelled to use the term ak-chin should be very explicit regarding the location of the field and why they have chosen to use the term.

Other Runoff Systems

Rankin and Katzer (1989) also discuss two other runoff systems defined by Nabhan (1979). In the arroyo bottom agricultural system, fields are located in the bottoms of ephemeral drainages or broad arroyos, and water flow is controlled by brush weirs or dams. In the second system, water from arroyos is diverted by weirs onto terraces or into storage basins. Such systems are referred to as terrace or storage basin inundation agricultural systems.

OTHER WATER UTILIZATION AND MANAGEMENT TECHNIQUES

The prehistoric inhabitants of Arizona used still other means to obtain water for domestic and agricultural purposes. Some of these techniques are manifested in the archaeological record of Arizona, while the presence or use of others remains speculative. Thus, some can be identified as property types and discussed in terms of NRHP eligibility, while others cannot. This discussion describes a variety of property types and water-management techniques that do not easily fit into specific categories. A very useful and recent detailed discussion of many of the water sources summarized below can be found in Ahlstrom (2000:7–65; see also Bryan 1925).

Seepage and Spring-Fed Fields

Seeps differ from springs in having flows of less than 5 gallons per minute (Ahlstrom 2000). Seepage fields (Glassow 1980; Hack 1942) are placed directly below seeps or springs. Such fields may also derive much of the moisture necessary for crop growth from direct rainfall or runoff or both. Nevertheless, it is the water seeping down from the source that makes the field arable. Ethnographically, Glassow (1980; see also Hack 1942) notes that such fields may be very difficult to discern from dry-farming fields in that the source of water may not necessarily be evident at the field site. Archaeologically, this would make recognition of such fields even more difficult. The presence of archaeological remains in proximity to a seep or spring in a situation suitable for an agricultural field might indicate the presence of such fields. Schoenwetter and Dittert (1968) suggest that this type of field water-management system may have been common in the Southwest before A.D. 200 and may have been of considerable importance to Early Agricultural period (Huckell 1995) peoples. Glassow further notes that Lipe (1970) is apparently referring to this type of field in his settlement-pattern study of the Red Rock Plateau in the Glen Canyon area.

Clearly the use of this type of water-management system was dictated by rainfall, geology, and topography. During periods of increased rainfall, seeps and springs would have been not only more plentiful, but more productive in terms of the amount of water available. Of course, the opposite would have been true during times of protracted drought. Such sites would be more common in the upland plateaus of northern and eastern Arizona, where geological formations and topography are more like to provide conditions for creation of seeps and springs.

Springs (also call pozos in southwestern Arizona) were certainly an important source of water throughout the prehistoric occupation of Arizona. Crown (1987a) notes examples of walled springs, natural springs with either masonry or log walls built around them in order to impound water. One such spring is reported by Haury and Hargrave (1931) at Kin Tiel in northeast-central Arizona. Water could have been used for both domestic and agricultural purposes.

Water Table Fields

The principal source of moisture for water table fields is groundwater. Such fields were placed on lowlands or in depressions near rivers, streams, or lakes that were low enough to take advantage of groundwater near the surface. It is also possible that fields were placed on points of land isolated in channel bottoms or on meander loops. These "islands" would be surrounded in part by flowing water and not necessarily inundated during times of flooding. Fields in these locations would be watered through capillary action from either the surface water or from groundwater in the streambed.

High water tables are also found in areas where the local geology (bedrock, dikes) forces groundwater closer to the surface. If the overlying soils are sandy, the roots of crops could easily penetrate the soil, while water is drawn to the surface by capillary action. Glassow (1980) notes that Schoenwetter and Dittert (1968) speculated that this technique may have been widely used prior to A.D. 200. Gumerman and Dean (1989) indicate that groundwater fields were likely widely used in Pueblo I and II times in the Kayenta area. Glassow further notes that this technique could have been used in many areas of the Southwest where it is not at all evident now. Changes in local topography (cutting and filling), vegetation patterns, and rainfall patterns (as well as modern human intervention) are some factors that could influence the level of groundwater. Thus, without any evidence of the conditions where high groundwater levels were present, identification of prehistoric use of such settings would be very difficult.

Ditches

The ditches considered here are not parts of the extensive canal and field systems associated with the Hohokam (see Chapter 5). Ditches are common in the Prehistoric Pueblo region, especially in the Kayenta branch area (Gumerman and Dean 1989). They are also found in the Little Colorado drainage and in the Hohokam area. Ditches generally appear to be used to divert water from rivers (perennial and ephemeral) and channel runoff onto agricultural fields. They may be difficult to identify, because most are earthen features that may have eroded into drainages or been filled. Stone-lined ditches have also been reported, and remain visible. Ditches are found in the Prehistoric Pueblo, Mogollon, and Hohokam areas. Most appear to date between A.D. 900 and 1400. A modern example of a diversion ditch is illustrated in Figure 4.1.

Dams and Dikes (Weirs)

Dams and dikes serve to impound or divert water or both. These features are constructed from earth and stone and are placed in streams to form ponds that provide domestic or agricultural water sources (Figures 4.2 and 4.3). The water impounded could have been drained off or diverted by the use of ditches that carried water to fields. Earthen dikes were and are also used to slow and divert rainfall runoff. Another form of dike or diversion is a brush weir or tree weir dike. These weirs are fence-like structures with vegetation woven in between the trees or posts (Figure 4.4). These, too, could have been and are used to slow and divert water, either from runoff or from flooding in streams, into ditches or across fields or slopes.

Figure 4.1. An example of a modern diversion ditch off the Río Sonora near Bavicora (courtesy of Paul and Suzanne Fish).

Figure 4.2. An example of a modern diversion dam on the Río Sonora (photograph courtesy of Paul and Suzanne Fish).

Figure 4.3. An example of a small earthen diversion dam or berm in the vicinity of the Río Sonora (photograph courtesy of Paul and Suzanne Fish).

Figure 4.4. An example of a tree row diversion weir in the vicinity of the Río Sonora (photograph courtesy of Paul and Suzanne Fish).

Catchment Basins and Retention Basins (Tinajas)

Catchments and retention basins are natural or constructed basins that are filled by direct rainfall or runoff. These features may provide water for domestic consumption, pot irrigation, or irrigation of plots or fields downslope (Masse 1991; Vivian 1974; Woosley 1980). Crown (1987a) has suggested that a distinction be made between catchment and retention basins:

> Retention basins would fill only with direct rainfall or slope wash from precipitation in an immediately surrounding area. Catchment basins could fill through surface flow from a larger area without the direct impact of rainfall or snowmelt in the immediate vicinity; the precipitation only had to occur within the drainage basins feeding the incised channels in which they were located ... [T]here are differences in the size of the two types of features, differences that probably reflect their relative reliability. For those features for which we have complete data, the retention basins are on average smaller than the catchment basins. ...Finally, differences exist in the construction of these two types of features. Catchment basins were constructed by placement of a barrier across a naturally incised channel, and hence additional excavation of a basin to hold water was typically not necessary. Most (75 percent) of these features are reported as occurring within natural rather than artificial basins. By contrast, 77 percent of the documented retention basins have basins that are artificial in origin. Taken together, then, the differences in the location, reliability, size, and construction of the features suggest that the typological distinction made here between catchment basins and retention basins is a potentially useful one [Crown 1987a:213–214].

The distinction made by Crown is worth noting, and although it might be viewed as splitting hairs, it is certainly a useful attempt to clarify how the two systems differ.

Retention basins, also known as tinajas (natural rock potholes, tanks, or erosional basins), are common throughout the Southwest, especially in slickrock or sandstone country. In southwestern Arizona these natural features provided water travelers through the Papaguería (e.g., Hayden 1972). Most such basins tend to be relatively small, and they were likely used for domestic water. Their use undoubtedly extends back to Paleoindian and Early Archaic period times. Tinajas typically form as plunge pools below falls or as eroded pools in bedrock. Some larger tinajas in protected (shaded and somewhat enclosed) areas are known to retain water for many months after rainfall. Sometime tinajas fill with sand, and water can be obtained by digging into the sediment (Bryan 1925). Broyles (1996) has identified 128 perennial and intermittent water holes in the mountains of the Western Papaguería. Problems with tinajas are that the water can foul quickly and that they often serve as traps for animals that come to drink from them.

Recent work in the Western Papaguería substantiates the prehistoric use of the area (e.g., Ahlstrom 2000; Hartmann and Thurtle 2001; Slaughter, Tucker, and Lascaux 2000). The presence of tinajas in this hot and arid setting undoubtedly allowed prehistoric peoples to pass through and hunt and collect in the area. Work in the Tinajas Altas Mountains (Hartmann and Thurtle 2001) has resulted in the recovery of Archaic period projectile points and Lower Colorado Buff Ware ceramics. Spier (1933) noted the importance of this area as a source of water to historic Yumans traveling through the area. Potter and Fox (2000) report the presence of tinajas along the southern edge of the New River Mountains north of Phoenix.

Related features are charcos, ephemeral ponds that form in pans in water channels. These pans are underlain by fine-grained alluvium that retards water seepage. Only the larger ones will retain water for any length of time (Ahlstrom 2000; Bryan 1925). Woosley (1980:Figure 3) illustrates a charco impounding hundreds of liters of water near Sells, Arizona.

One very interesting example of a retention basin system, recorded as NA 4604 at the Museum of Northern Arizona, comes from the files of Richard Woodbary. It is a water-collection system (Figure 4.5) on Battleship Mountain north of Lupton in Apache County. The system drains at least 2 acres with a series of channels that connects several retention basins (potholes) of various sizes. The channels direct water to the basins via natural fault lines in the sandstone formation. However, in some areas the fault lines were extended or enhanced by pecking grooves into the sandstone, some of which are as much as 17 cm wide and 13 cm deep. The system was set up to capture runoff as well as overflow from some of the larger basins. The two largest basins measure 10 by 20 m by about 1.5 m deep and 3.5 by 5 m by 1.75 m deep. A third is about 3.5 m in diameter and nearly 2 m deep.

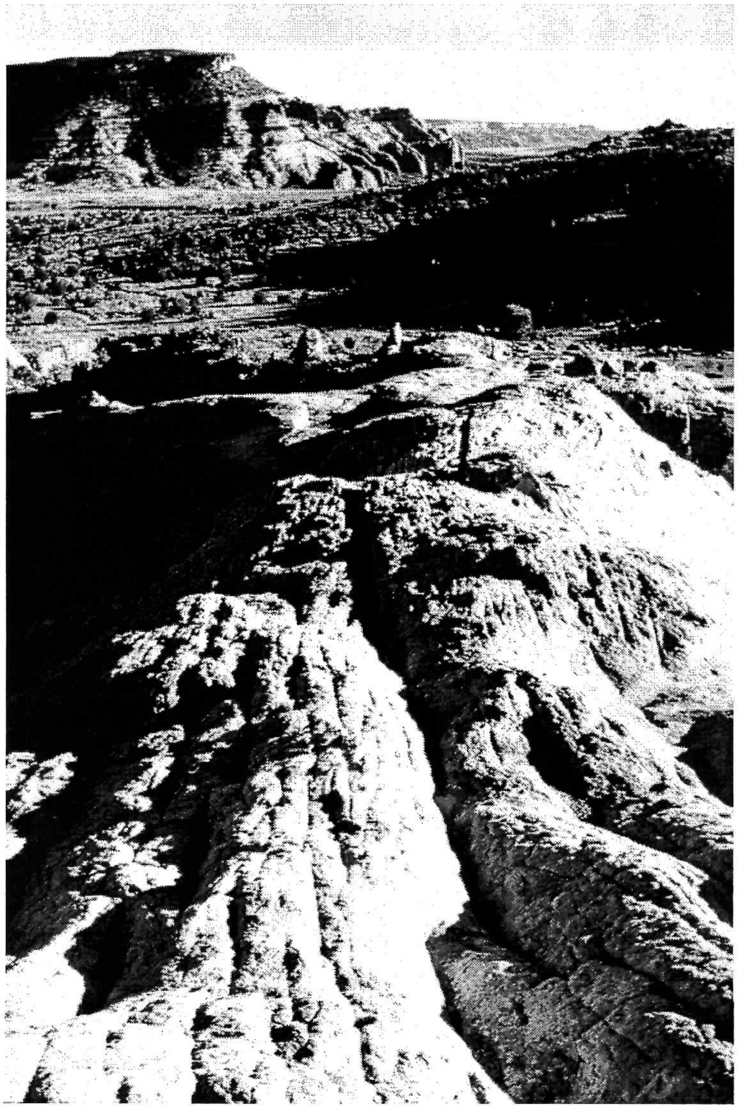

Figure 4.5. An illustration of one of the Battleship Mountain catchment systems with a natural fault running to a catchment basin (photograph from the files of Richard Woodbury, courtesy of Paul Fish).

A current survey of the Agua Fria National Monument by SWCA has resulted in the identification of several large tinajas in Alkali Canyon on the west edge of Black Mesa (Ronald Ryden, personal communication 2001). Ryden believes that these features served as water sources for a nearby pueblo.

Crown (1987a) reports that catchment or retention basins are also enhanced by the construction of a retaining wall along one edge of the basin to slow and divert runoff. Such features generally appear to date after A.D. 700. In the Western Prehistoric Pueblo area of northeastern Arizona, Gumerman and Dean (1989:123) note that during Pueblo III times (A.D. 1150/1250–1300; Tsegi phase) many of the lowland sites were located near springs, tanks, and reservoirs. The need to locate near or construct retention basins may have been tied to a drop in local water tables.

Reservoirs

Reservoirs are basins or pools that are constructed to retain water. They may be excavated (built) features, or they may be natural features modified by humans to facilitate the retention of water. They can be used to capture water for domestic purposes or agricultural purposes or both. Gumerman and Dean (1989:123) indicate that the use of reservoirs during Pueblo III times (Tsegi phase) in the Western Prehistoric Pueblo area was of great importance for the collection and storage of domestic water, especially in the eastern lowlands.

A number of Hohokam reservoirs have been identified (e.g., Antieau 1981; Bayman 1992, 1993 Bayman and Fish 1992; Bayman, Palacios-Fest, and Huckell 1997; Ciolek-Torrelo and Nials 1987; Crown 1984a, 1987a; Dart 1983a; Rabb 1975; Wilcox and Sternberg 1983). These features vary in size and complexity. Raab (1975) describes excavation of a reservoir sites, AZ AA:5:43(ASM), on Santa Rosa Wash on the northern edge of the Tohono O'odham Reservation. The feature appears to be about 25 m wide, 43 m long, and 3 to 4 m deep, with an inlet channel in its southwest corner and an overflow channel in its southeast corner. A second site, AZ AA:5:54(ASM), was also thought to be a reservoir. Bayman (1992) discusses numerous constructed reservoirs at sites along the San Pedro River in southern Arizona.

Crown (1984a) discusses reservoirs recorded on the south side of Queen Creek during the Salt-Gila Aqueduct Project. She suggests that these features were fed by groundwater and channeled runoff. The largest of the reservoirs investigated, at AZ U:15:61(ASM), had an extimated maximum capacity estimated to be 295,000 liters. The two largest reservoirs did not have outlets and are thus interpreted to be domestic water storage facilities, although the water they held could have been used in pot irrigation. Furthermore, Crown indicates that these features apparently started out as wells and were expanded to reservoirs. The third and smallest reservoir had a break in its downslope embankment, but it is not known if this was a natural or intentional feature.

Crown (1984a) describes four small pools found in the Florence area. These features were not big enough to be considered reservoirs and are perhaps better thought of as artificial retention or catchment basins. The capacity of the largest was estimated to be nearly 2,500 liters. One was located above a rock pile field and perhaps held water for diversion onto the rock pile field below.

Bayman, Palacios-Fest, and Huckell (1997) investigated a reservoir at AZ AA:3:323(ASM) located north-northwest of Tucson that measured 40 by 70 m and was at least 3.5 m deep. A dirt embankment that was believed to have been at least 2 m high surrounded this feature. The results of the investigation of this reservoir lead Bayman, Palacios-Fest, and Huckell to suggest that the feature was likely a long-term water storage facility (see also Bayman 1997). They recovered duckweed seeds (*Lemna*) from the feature and interpreted the presence of this plant to indicate that the feature retained water for considerable periods of time. These investigators also cite evidence from other sites, for example, the presence of an aquatic mud turtle and the common reed at the site of Gu Achi, as indications that reservoirs were used for long-term water storage. Summary data from Bayman (1993) indicate that reservoirs typically range from 17 to 70 m in length and 17 to 62 m width. The greatest depth he notes is 6.85 m, with depths in the 1–2 m range being more typical.

In summary, reservoirs generally appear late in Western Prehistoric Pueblo context A.D. 1250–1300 (Gumerman and Dean 1989). In the Hohokam area these features date from the late Pioneer period through the Classic period (Bayman 1993). A potential Late Archaic period reservoir has been reported in the Tucson Basin (Bernard-Shaw 1989), and it is highly likely that future research will result in the identification of numerous early examples. Bayman (1993) notes that reservoirs are widespread in the Hohokam area, with a particularly interesting cluster in the nonriverine desert that divides the Phoenix and Tucson Basins. One potential problem with identifying reservoirs from surface manifestations alone is that they may be confused with ballcourts, or vice versa (Bayman 1993; Wilcox and Sternberg 1983).

Wells

The limited availability of surface water in the Southwest placed a premium on knowledge of locations where this vital resource could be obtained. By at least 8,000 years ago, the prehistoric inhabitants of the region learned to obtain water by excavating wells. Although evidence for this type of feature has been identified at only a limited number of locations, it is possible that wells were relatively common (Crown 1987b:223; Woodbury and Zubrow 1979:52). It is difficult to estimate the actual incidence of these features as they generally occur in contexts where archaeologists are unlikely to excavate (for example, wash bottoms), and they frequently lack materials or artifacts that allow temporal placement. Consequently, wells that are encountered might be assumed to be of recent origin.

Prehistoric wells in the Southwest were first identified near Clovis, New Mexico. These features were only approximately dated, to the period between 3000 and 200 B.C. (Evans 1951). Wells that may have dated as early as 6000 B.C. were identified at the Lehner site and in preceramic contexts at Murray Springs (Crown 1987b). A well identified at Rattlesnake Draw in New Mexico was inferred (based on limited evidence) to have been created around 5000 B.C. (Smith et al. 1966:306). A series of wells identified at Mustang Springs in western Texas produced uncalibrated radiocarbon and thermoluminescence age estimates of between 8000 and 5000 years ago (Meltzer and Collins 1987).

Emil Haury identified wells at two separate locations in Arizona. At the Cienega Creek site, large pits were identified that varied between 1 and 3.7 meters in depth (Haury 1957). These wells could only be dated to about 2000 B.C. and were thought to be associated with Cochise culture (Southwestern Archaic) occupation of the site. Haury (1976:152–153) also discusses several types of Hohokam wells at Snaketown. One is a vertical-wall type. The example excavated at Snaketown was about 2 m deep from its original desert surface. Haury suggests that water was retrieved from this type of well using a rope lift, presumably a cord attached to a pot or gourd, or perhaps a skin water bag. He also describes walk-in wells at Snaketown. These wells are inverted cones in profile, and it is assumed that water was retrieved by walking into them. Upon abandonment, the Snaketown wells were used as trash pits. The ceramics present indicate that the wells were in use throughout the Pioneer period, and as Haury notes, it is likely that the earlier Hohokam and their predecessors (as noted above) were skilled in the art of digging wells.

More recently, four probable wells were identified on the Santa Cruz River floodplain in Tucson (Gregory 2001:82-86), and at least eight wells were identified within the channel of McClellan Wash in the middle Gila River valley. None of the Santa Cruz wells were directly dated, but redware sherds were recovered from the fill of one of the features, suggesting that it at least partially filled during the Tortolita phase, several centuries after the Early Agricultural occupation of the site (Gregory 2001:82).

Excavation of the McClellan Wash wells produced only two small flakes (Loendorf et al. 2002). The lack of ceramics in the fill of these wells suggests that they predate the introduction of ceramics in the area. Radiocarbon samples recovered from several of these features should provide a more accurate age estimate for their use.

The wells consisted of pits roughly 0.5–2 m in diameter and less than 4 m deep. They were excavated into or near drainages, and the pits were generally funnel shaped, although some were conical or cylindrical in profile (Figure 4.6).

Figure 4.6. Probable Archaic period wells in McClellan Wash. Plan view of exposed well below, profile of another well in the trench face (photograph courtesy of the Gila River Indian Community Cultural Resource Management Program).

Playas and Cienegas

Playas are dry lakebeds that fill with water during rainy seasons (e.g., Waters and Woosley 1990). Like charcos, playas are underlain with fine-grained alluvium that significantly slows water seepage. Surface water may remain for several weeks after the end of rains, and these features also can be dug into to obtain water (Ahlstrom 2000; Bryan 1925). Cienegas are swampy areas or wetlands (see Huckell 1995:18); water can be obtained from them by digging as well (Ahlstrom 2000). It is likely that such areas have a long history of use in the moisture-starved environment of prehistoric Arizona (e.g., Waters and Woosley 1990).

SUMMARY

Many of the water-management and utilization property types and strategies described in this chapter may be difficult to recognize archaeologically. Nevertheless, these water technologies certainly played vital roles in the lives of the prehistoric peoples of Arizona. As emphasized in this document, one of the problems in the literature on prehistoric water technology is the frequent misuse of terms. For example, floodwater farming is often confused with runoff agriculture, and the term ak-chin is generally misapplied. Floodwater (inundation) farming utilizes the overflow of streams and rivers as a means of watering garden plots or fields that are located within the floodplains of drainages and thus may be difficult or impossible to identify because of flooding, erosion, and alluviation after abandonment. Runoff agricultural systems, on the other hand, use the runoff from rainfall, and these systems may be easier to identify in that they often have associated features that directed the flow of runoff to fields or portions of fields or that controlled the velocity of the runoff.

Ak-chin, a Tohono O'odham word that means a place rather than a field or farming technique, is frequently misused in the archaeological literature. We suggest that it be replaced with the term alluvial fan floodwater farming. Additionally, the term ak-chin properly has relevance only to the O'odham cultural. The use of a culturally neutral term, alluvial fan floodwater farming, would more appropriate outside of O'odham territory. Alluvial fan floodwater farming is more labor intensive than floodwater inundation in that small ditches and diversion features are often employed to direct water towards fields.

Other water utilization and management techniques related to agriculture include seepage and spring-fed fields and water table fields. As with floodwater inundation fields, fields associated with these techniques may be difficult to identify based on surface evidence alone. Obviously, if there has been some cultural modification of the seep or spring, such as an impounding wall, it is easier to identify potential field locations. The presence of habitation sites, farmsteads, and field houses might also provide clues to the location of such fields. Some researchers have suggested that early agriculturalists in the Southwest utilized these water sources.

Additional water-management features are ditches other than those associated with extensive Hohokam canal systems, dams, and dikes (weirs). The ditches discussed are those that divert water from streams (ephemeral or perennial) and runoff to fields. The dams and dikes serve to impound water for diversion, to slow water flow across fields, or to redirect water flow.

Some water collection and storage facilities served domestic purposes and may or may not have been associated with agriculture. These features include catchment basins, retention basins (tinajas), reservoirs, and wells. Other types of features, such as playas, cienegas, and charcos are natural ponds or wetlands that fill with runoff during rainstorms and retain water. The water from these features also was probably used for domestic purposes, although it could have been used in pot irrigation or diverted to agricultural plots. These features, a combination of both natural and culturally altered, likely have long histories of use in the arid environs of prehistoric Arizona. Wells probably date back to the Paleoindian period, and features such as tinajas undoubtedly supplied water to the early hunters and hunter-gatherers of the area as well.

A final observation is that there is no substantial evidence for the prehistoric use of Arizona's navigable rivers for transportation. No evidence of boats or other watercraft being used to cross rivers or to move people and goods up and down rivers has been identified in the archaeological record. In fact, larger rivers and streams, especially during flood stage, probably impeded movement. However, the river valleys themselves clearly served as corridors for the movement of people and as trade routes. These river valleys also provided water, rich alluvial soils, places for people to hunt and fish, and grow crops, and places for people to live. Despite the role of important role of rivers in prehistoric Arizona, the use of their waters appears to be primarily related to domestic and agricultural activities.

CHAPTER 5

PREHISTORIC CANAL IRRIGATION IN ARIZONA

M. Kyle Woodson and Gary Huckleberry
with a contribution by Jeffrey L. Eighmy

Irrigation canals have been constructed for over 3,000 years by indigenous peoples in both the lowland and upland deserts of Arizona for the primary purpose of food production. Hundreds of miles of these waterways still remain wholly or partially intact both at and below the surface. As one of a number of diverse agricultural traditions utilized in the state, canal irrigation systems often were the lifeblood of ancient communities. The vestiges of these hydraulic systems are a testament to the technological prowess and ingenuity of prehistoric agricultural societies, and they represent an important part of Arizona's rich cultural heritage. This chapter presents a historic context for prehistoric canal irrigation in Arizona.

Irrigation is the artificial application and distribution of water to otherwise dry lands in order to facilitate cultivation (Doolittle 1990:12, 2000:347; Monkhouse 1965:173). Canal irrigation is "a specific form of irrigation that involves the transport of water from a source by means of gravity flow through artificially constructed open conduits or canals" (Doolittle 1990:12). A canal system may be defined simply as the aggregate of irrigation features that are associated with a single headwater or intake location, including at least one canal (but potentially many canals). Doolittle (2000:309, 347; Lawton and Wilke 1979:4–5; see also Masse 1980a:198, 201) further distinguishes canal irrigation as that technology associated with the diversion of water from permanent or perennial sources (i.e., rivers and springs) in contrast to diversion water from ephemeral, intermittent, or seasonal streams (see Chapter 4). The latter is a method of water harvesting, a general technique of altering drainage basins upslope or upstream of field to increase runoff and divert it to crops (Doolittle 2000:309). Canals in water-harvesting systems tend to have much steeper gradients and are "less refined or polished" than canals that form irrigation systems (Doolittle 2000:345). Regardless of the water source, however, canal systems consist of similar components, as reviewed in this chapter.

The prehistoric canal systems in Arizona were earthen, gravity-fed systems designed at a relatively simple technological level (Haury 1976; Nials and Gregory 1989:51; Woodbury 1960). The majority of these systems diverted water from perennial rivers and streams along valley bottoms, but many water-harvesting systems that utilized water from intermittent streams and washes along alluvial fans, or bajadas, also occur in the state. The most extensive and complex canal systems were those of the Hohokam in the Phoenix Basin (Figure 5.1). The operation of these large, intricate systems required considerable labor and management. However, most canal systems in other parts of Arizona were not as extensive as those in the Phoenix Basin. The diversity of irrigation structures in Arizona and the settings in which canal systems were built are representative of the impressive array of structures and settings used throughout the arid Southwest.

For well over a century, archaeologists and laypeople alike have been intrigued by the high visibility, sophistication, and extent of Arizona's prehistoric canal systems. Many archaeological investigations have revealed surface and subsurface evidence of these irrigation systems in watersheds throughout the state. This previous work has contributed immensely to our knowledge of prehistoric canal systems, including their location, age, and spatial extent; their morphological, technological, hydraulic

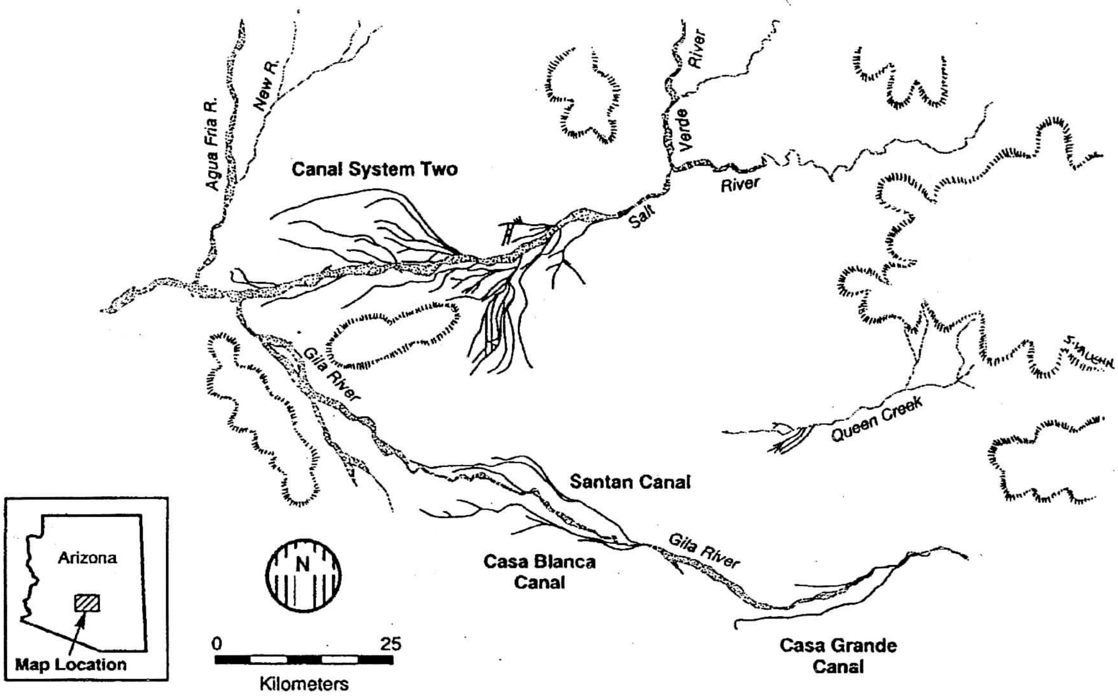

Figure 5.1. Map of Hohokam canal systems in the Phoenix Basin (adapted from Rice 1998:269; courtesy of *Kiva* and the Arizona Archaeological and Historical Society).

(e.g., water velocity, discharge), and ecological (e.g., water salinity, seasonality of use) characteristics; and their patterns of growth and development. In addition, canal research has figured substantially in studies of prehistoric cultural evolution, such as the impact of streamflow variation on canal system integrity and agricultural productivity and the possible modes of social organization that may have integrated the builders of these systems. Although progress has been impressive in understanding prehistoric irrigation, many important questions remain and are deserving of further study.

This chapter begins with an overview of the cultural and temporal settings and the spatial distribution of canals and irrigation features in Arizona, followed by a description of the property types associated with canal irrigation systems. The methods of documenting and analyzing abandoned (relict) irrigation features, with specific emphasis on canals, are summarized, and guidelines are presented for situating the interpretation of prehistoric canal systems and irrigation features within broader environmental and cultural contexts.

CULTURAL AND TEMPORAL SETTING OF CANAL IRRIGATION IN ARIZONA

The earliest known irrigation canals in North America were built in the floodplain of the middle Santa Cruz River in the Tucson area (Doolittle 2000:372; Mabry 2002; Muro 1998). These small, short canals were built between 1100 B.C. and 1000 B.C. during the Early Agricultural period (1700 B.C.–A.D. 1/150) near villages that also occupied the floodplain. These canals are contemporaneous with the earliest known canals in Mesoamerica and the Andes (Doolittle 2000:372), supporting the contention that canal irrigation was developed independently in the American Southwest (Doolittle 1990:80). Although

2,000 feet) in the Tucson Basin, such as along Cienega Creek (Huckell 1995), and in southeastern Arizona, such as in the upper Gila Valley near Kearny and Safford (Clark 2000; Clark 2002), no other canals currently are known from the Early Agricultural period.

During the first part of the Early Formative period (around A.D. 1/150–450/550), evidence suggests that a shared cultural pattern existed across southern Arizona (Cable and Doyel 1987; Ciolek-Torrello 1995; Doyel 1993b; LeBlanc 1982; Sayles 1945; Whittlesey 1995). This lifeway pattern was characterized by circular, oval, and bean-shaped pit houses; large communal houses; plainware pottery; large projectile points; basin and slab metates; flexed and seated inhumation and primary cremation; and floodwater agriculture. Based on a current assessment of available data, small canals were first built in the Phoenix and Safford basins during this time, but canal technology does not yet appear to have been widespread in Arizona. The earliest dated canals in the Phoenix Basin include one in the lower Salt Valley, which dates to between 130 B.C. and A.D. 275 (Henderson 1989:196), and one in the middle Gila Valley, which dates to 185 A.D. ±60 (Waters and Ravesloot 2000:53). A recently discovered canal in the upper Gila Valley near Safford dates between A.D. 1 and 300 (Clark 2002). During the latter part of the Early Formative period (around A.D. 450/550–650; Vahki phase in the Phoenix Basin, and Tortolita phase in the Tucson Basin), regional cultural distinctions began to emerge as populations embraced new ceramic, architectural, and other material traits along with changes in subsistence-settlement patterns (Ciolek-Torrello 1995; Doyel 1991, 1993b; Whittlesey 1995:474). Canal systems remained small in the Phoenix Basin and presumably in the Safford Basin. Although the earliest canals in Arizona were built in the Tucson Basin, currently no Early Formative period canals have been identified there. No canals have been identified in other parts of Arizona from this time.

Although these early irrigation systems were small and simple, it was the Hohokam who built the most extensive canal systems in the pre-Columbian New World (Figure 5.2; see also Figure 5.1). The emergence and archaeological identification of the Hohokam as an integrated cultural pattern occurred during the Snaketown phase (A.D. 700–750) of the Pioneer period, although a much earlier origin beginning around 300 B.C. originally was proposed (Gladwin et al. 1937; Haury 1976). Recent assessments suggest that the Hohokam cultural trait complex was not fully developed until the Snaketown phase or even the subsequent Gila Butte phase (A.D. 750–850) of the Colonial period (Wallace 1997; Wallace, Heidke, and Doelle 1995; Wilcox 1979; Wilcox and Sternberg 1983). Canal irrigation agriculture was a primary focus of Hohokam communities throughout their existence between A.D. 700 and 1450. Many systems eventually incorporated multiple canals that in some cases were over 30 km (18.6 miles) in length and carried water up to 16 km (10 miles) away from the river. Although a great deal of experimentation undoubtedly occurred during the development of irrigation systems in Arizona, the basic technology of these hand-dug, gravity-fed canals was not complex. Nevertheless, the productivity of these systems allowed the Hohokam to flourish in the desert for nearly 800 years. Hohokam groups built canals in other areas of the state, including the Tucson Basin, lower Verde Valley, Tonto Basin, and Papaguería, although these systems were not as extensive as those found in the Phoenix Basin. Notably, no prehistoric canals have been identified in the San Pedro Valley.

Although the Hohokam systems represent the paragon of canal irrigation in the prehistoric American Southwest, other cultural traditions in Arizona utilized canal irrigation systems to a lesser degree during what may generally be termed the Late Formative (A.D. 700–1000) and Classic (ca. A.D. 1000–1450) periods (Doyel 1993b; see Figure 5.3). The Sinagua are recognized as a cultural group during the Classic period in the upper Verde Valley and on the Colorado Plateau around Flagstaff. Canals have been reported at several Sinagua sites, such as Tuzigoot and Montezuma Well. Salado is the traditional designation for Classic period groups in the Tonto Basin and other parts of southeastern Arizona, associated with Gila Polychrome pottery, platform mounds, inhumation burial, and room block architecture. However, the definition of Salado remains problematic (Dean 2000). Recent studies (e.g.,

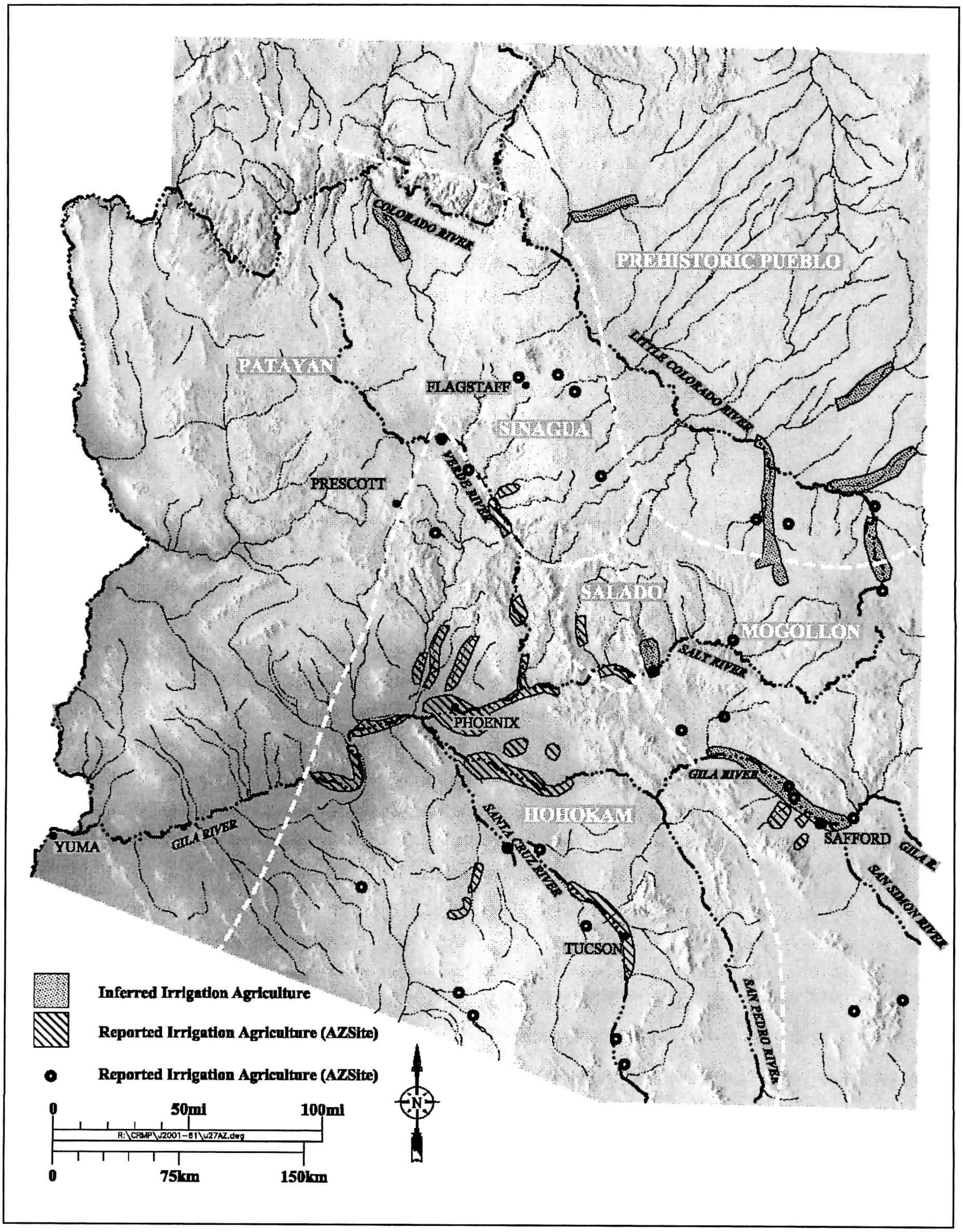

Figure 5.2. Location of reported and inferred prehistoric canals and other irrigation features in Arizona.

Elson, Gregory, and Stark 1995; Nelson and LeBlanc 1986:6–7; Rice 1990:22–27) argue against the Salado as an archaeological culture, but they support the thesis of Salado as a broad, regional horizon beginning around A.D. 1250. Regardless, several canals associated with Salado horizon settlements are known in the Tonto Basin area (Waters 1998). Ancestral Pueblo and Mogollon groups in east-central and northeastern Arizona also practiced irrigation on a limited scale during the Late Formative and Classic periods. However, although the Safford Basin and other parts of southeastern Arizona traditionally have been considered part of both the "Mogollon" and the "Salado" culture areas, the Hohokam and Prehistoric Puebloans also clearly played a role in the cultural development of this area (Crary, Germick, and Doyel 2001; Gregory 1995). Hence, cultural designations also are problematic for most groups practicing irrigation in southeastern Arizona. No prehistoric canals have been identified at Patayan sites in western and southwestern Arizona, in the lower Colorado and lower Gila valleys.

No canals have been confidently identified by archaeologists that date to the Protohistoric period (A.D. 1450–1700), the time between the end of the Classic period and Spanish contact (see Wilcox and Masse 1981). However, some researchers suggested the presence of canals at sites, for example AZ DD:8:126 (ASM), in the upper Santa Cruz Valley (AZSite 2001; Di Peso 1956). The archaeology of the Protohistoric period remains poorly understood throughout southern Arizona, largely due to the small sample of excavated material, poor chronometric control, and lack of a cohesive interpretive framework (Ravesloot and Whittlesey 1987). As a result, the primary sources of information are Spanish ethnohistorical accounts, which are relevant primarily to the period of contact and probably the late Protohistoric period. Based on the earliest accounts by Captain Manje (1954; see also Burrus 1971), who traveled with Father Kino, canal irrigation was being practiced by Sobaipuri (Upper Piman) groups in the middle Santa Cruz and San Pedro valleys (see also Burrus 1971; Doelle 1984). In the middle Gila Valley, however, interpretations of Manje's accounts (Doelle 1981; Wilson 1999; Winter 1973) suggest that the Akimel O'odham (Gila River Pima) were not using canals at the time of Spanish contact. Nevertheless, these accounts are not necessarily applicable to the time between the collapse of the Hohokam and Spanish contact in southern Arizona.

SPATIAL DISTRIBUTION OF CANALS AND IRRIGATION FEATURES IN ARIZONA

Prehistoric canals and irrigation features have been documented in numerous parts of Arizona (see Figure 5.2; Table 5.1). As reviewed by Dart (1989:6–7), several environmental and cultural factors appear to have influenced a prehistoric group's decision about where to pursue canal-irrigation agriculture. Other than the obvious environmental requirement of an aboveground stream (or spring) as a water source, farmers had to be able to divert water from a stream into a canal by gravity-fed means alone. Thus, streams with rocky banks or deeply incised channels were not ideal water sources because of the additional labor required to dig through their high banks. In addition, the stream had to flow during the frost-free portion of the year when plants could be cultivated, and it had to provide sufficient water (in addition to rainwater) for a crop to become established and reach maturity.

Although many rivers and streams in Arizona meet these conditions, some were not used as sources for canal irrigation even though prehistoric groups occupied the potentially irrigable area. The decision not to irrigate may be partially explained by three cultural factors. First, canal irrigation represents a type of agricultural intensification, which entails increasing agricultural output per unit of land and time (Boserup 1965; Netting 1993; Turner and Doolittle 1978). Irrigation is hard work, requiring significant increases in time and effort in comparison to extensive food production strategies and wild food gathering. Thus, people generally will not adopt irrigation unless induced to do so. Such a decision tends to be a response to an increase in population density and land scarcity coupled with a decrease in mobility options (e.g., Boserup 1965; Netting 1993; Stone 1996); however, other factors such as risk

Table 5.1. Drainages and Streams in Arizona with Reported or Inferred Prehistoric Canal Irrigation Features.

Drainage Basin/River Valley	Irrigation Features Reported or Inferred?	Selected References
Phoenix Basin		
Lower Salt River	Reported	Ackerly and Henderson 1989; Ackerly et al. 1987; Bandelier 1892; Greenwald and Ciolek-Torrello 1988; Greenwald et al. 1996; Hackbarth et al. 1995; Halseth 1932; Haury 1945; Howard 1987, 1990; Howard and Huckleberry 1991; Huckleberry 1999a; Masse 1976, 1981, 1987; Midvale 1968, 1971; Mitchell and Motsinger 1998; Nials and Fish 1988; Patrick 1903; Turney 1929; Woodbury 1960
Middle Gila River	Reported	Brooks and Vivian 1978; Craig and Phillips 2001; Crown 1984a, 1984b; Dart 1983a; Haury 1937, 1976; Midvale 1963, 1965; Woodson 2002
Queen Creek	Reported	Brooks and Vivian 1978; Crown 1984a; Dart 1983a; Turney 1929
Agua Fria River	Reported	Dove 1977; Midvale 1971; Turney 1929; Weed and Ward 1970
New River	Reported	Doyel 1984, 1985; Doyel and Elson 1985; Midvale 1969, 1971; Rankin and Katzer 1989; Turney 1929
Cave Creek	Reported	Midvale 1971; Henderson and Rodgers 1979; Holiday 1974; Rodgers 1977; Smith 1977
Lower Gila Valley	Reported	Doyel 2001; Midvale 1970, 1971, 1974; Rodgers 1976; Turney 1929; Wasley and Johnson 1965
Verde Valley		
Lower Verde River	Reported	Canouts 1975; Hagenstad 1969; Midvale 1946, 1971; Mindleff 1896; Van West and Altschul 1997
Upper Verde River	Reported	Fewkes 1898; Hartman 1976; Midvale 1971; Mindleff 1896; Schroeder 1960
Beaver Creek	Reported	Breternitz 1960; Fewkes 1898; P. Fish and S. Fish 1984; Midvale 1971; Mindleff 1896; Schroeder 1958, 1960
Tucson Basin and Vicinity		
Middle Santa Cruz River	Reported	Bernard-Shaw 1988, 1989; Fish, Fish, and Madsen , eds. 1992; Mabry 2002; Mabry and Holmlund 1998
Upper Santa Cruz River	Reported	AZSite 2001 (AA DD:8:42 and EE:10:6 [ASM])
Blanco Wash*	Reported	AZSite 2001 (AA AA:11:5 [BLM])
San Pedro Valley**	Inferred	Manje 1954; Masse 1980b
Tonto Basin and Vicinity		
Tonto Creek	Reported	Waters 1998
Upper Salt River	Reported	Bandelier 1892; Tagg 1985; Waters 1998; Wood 1986
Carrizo Creek	Reported	Bandelier 1892
Cherry Creek	Reported, Inferred	Wells 1971

Drainage Basin/River Valley	Irrigation Features Reported or Inferred?	Selected References
Safford Basin and Vicinity		
Upper Gila River	Reported, Inferred	Bandelier 1892; Botsford and Kinkade 1993; J. Clark 2002; Fewkes 1904; Haury 1984
San Carlos River	Reported	Bandelier 1892; Mitchell 1986
Marijilda Canyon	Reported	Doolittle 2000:318–321; Neely 2001; Neely and Rinker 1997
Lefthand Canyon	Reported	Doolittle 2000:318–321; Neely 2001; Neely and Rinker 1997; Rinker 1998
Taylor Canyon	Reported	Doolittle 2000:318–321; Neely and Rinker 1997; Neely 2001
Sulphur Springs Valley	Reported	Sauer and Brand 1930
Little Colorado River and Tributaries		
Upper Little Colorado River	Reported, Inferred	Bandelier 1892; Danson 1957; Lightfoot and Plog 1984
Moenkopi Wash**	Inferred	Dart 1989:17
San Francisco Wash	Reported	Breternitz 1957b; Pilles 1979
Schultz Creek	Reported	Breternitz 1957a
Young's Canyon	Inferred	Fish et al. 1980
Jack's Canyon	Reported	Lightfoot and Plog 1984
Anderson Canyon	Reported	Fish et al. 1980; McGregor 1958
Show Low Creek	Reported, Inferred	Lightfoot and Plog 1984
Silver Creek	Reported, Inferred	Lightfoot and Plog 1984
Hay Hollow Draw	Reported	Lightfoot and Plog 1984
Puerco River**	Inferred	Dart 1989:17; AZSite 2001 (AZ K:15:2 [ASM])
Zuni River**	Inferred	Dart 1989:17; Kintigh 1984
Colorado River and Minor Tributaries		
Cataract Creek**	Inferred	Schwartz 1956
Papaguería		
Santa Rosa Wash	Reported	Masse 1980a; Raab 1975
Greene Wash	Reported	AZSite 2001 (AZ AA:6:9 and AA:6:10 [ASM])
Anegam Wash	Reported	Dart 1989; Masse 1980a; Raab 1975
Midway Wash	Reported	AZSite 2001 (AZ Z:10:1 [BLM])
Vamori, Fresnal Wash	Reported	Withers 1973
Sells Wash	Reported	AZSite 2001 (AZ Z:10:1 [BLM])

* Questionable report of irrigation feature

** Inference of irrigation based on speculation; no irrigation features have been documented in this drainage.

aversion, market demand, or social production (see McGuire 1984) can influence the decision for intensification. Second, and related to the first, a sufficient labor force is necessary to build and maintain a canal system. Third, the preference for traditional, non-intensive subsistence methods in some potentially irrigable areas may have been a source of resistance to the adoption of irrigation technology.

This summary of the spatial distribution of canals and irrigation features in Arizona includes cases of reported and inferred canal irrigation features in a number of natural drainage basins and river valleys: the Phoenix Basin, lower Gila Valley, Tucson Basin and vicinity, Verde Valley, Tonto Basin and vicinity, Safford Basin and vicinity, Little Colorado River (and tributaries), Lower Colorado River (and tributaries), and Papaguería.

Phoenix Basin

The Phoenix Basin encompasses the lower Salt Valley, the middle Gila Valley, the Agua Fria and New rivers, and Queen Creek. As mentioned above, the most extensive and sophisticated canal systems in the Southwest can be found in this geographic area.[1]

Lower Salt Valley

The Hohokam canal systems in the lower Salt Valley (Figure 5.3) are the most intensively studied prehistoric irrigation systems in the United States (Dart 1989:7; Doolittle 2000:396–397). At least 20 canal intakes and numerous canals have been documented or inferred in the lower Salt Valley; however, most of these canals are grouped into four primary canal systems: the Los Muertos/Las Acequias canal system (Turney's [1929] Canal System 1), Canal System 2, the Scottsdale and Lehi canal systems (see Figure 5.1). The first maps of these systems were produced by some of the first interested researchers in the area (e.g., Bandelier 1892; Halseth 1932; Haury 1945; Hodge 1893; Midvale 1968, 1971; Patrick 1903; Schroeder 1943; Turney 1929). The first aerial photographs of Hohokam canals were produced by Judd (1930, 1931). Although canals were investigated during the Hemenway expedition in the 1880s (Haury 1945; Hodge 1893), Woodbury (1960) can be credited with initiating the first systematic excavations of ancient canals in Arizona at Pueblo Grande (Doolittle 2000:402).

More recently, numerous studies have been conducted as part of CRM projects in Canal System 2 (e.g., Ackerly, Howard, and McGuire 1987; Greenwald et al. 1996; Greenwald and Ciolek-Torrello 1988; Howard 1990; Howard and Huckleberry 1991; Masse 1976, 1981; Nials and Fish 1988; Nicholas 1981), the Los Muertos canal system/Canal System 1 (Ackerly and Henderson 1989; Herskovitz 1981; Masse 1987; Mitchell and Motsinger 1998), the Scottsdale canal system (Hackbarth, Henderson, and Craig 1995), and the Lehi canal system (Howard 1987). These investigations have vastly expanded our knowledge of prehistoric irrigation in the lower Salt Valley. For instance, the earliest irrigation canal has been dated to between 130 B.C. and A.D. 275 (Henderson 1989:196). However, canal construction does not appear to have begun in earnest until the advent of the Hohokam around A.D. 700. In addition to the extensive documentation of canals, a number of other irrigation features have been investigated during these projects. These features include sluice gates (or head gates; Ackerly, Howard, and McGuire 1987), reservoirs (Ackerly, Howard, and McGuire 1987), and settling basins (Nials and Fish 1988), as well as some field features (Howard 1990).The Hohokam also built canals along Cave Creek, a wash at the western end of Canal System 2 that terminates in a delta just north of the Salt River (Henderson and Rodgers 1979; Holiday 1974; Midvale 1971; Rodgers 1977; Smith 1977).

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[1] Detailed histories of research on canal irrigation systems in the Phoenix Basin can be found in Ackerly and Henderson (1989), Ackerly, Howard, and McGuire (1987), Doolittle (2000), and Howard and Huckleberry (1991).

Middle Gila Valley

The middle Gila Valley comprises that portion of the Phoenix Basin between the Buttes, about 26 km east of Florence, to the confluence of the Gila and Salt rivers. In the middle Gila Valley, the earliest irrigation canal was established circa A.D. 185 ±60, during a period of river channel stabilization (Waters and Ravesloot 2000:53). As in the lower Salt Valley, canal construction does not appear to have begun in earnest until the advent of the Hohokam around A.D. 700. This was followed by over 700 years of canal system development and expansion, with at least six, and perhaps seven[2], canal systems built by the Hohokam during this time (Figures 5.4 and 5.5). Two of these systems are over 30 km (18.6 miles) in length. Increasing human occupation through the Colonial (A.D. 750–950) and Sedentary (A.D. 950–1100) periods ended during the Classic Period (A.D. 1100–1450), when sites were abandoned and canals were consolidated (Crown 1991; Doyel 1991; Haury 1976; Wilcox 1979). A significant period of channel downcutting and widening (800–950 cal yr B.P.) in the Sedentary-to-Classic period transition likely created major problems for Hohokam agriculturalists and probably contributed to the reorganization seen in the archaeological record (Waters and Ravesloot 2000, 2001; Woodson and Davis 2001).

Although the Hohokam canal systems in the middle Gila Valley have not been investigated as intensively as those in the lower Salt Valley, some influential early canal studies were conducted by Cummings (1926), Midvale (1963, 1965; also Mitalsky [Midvale] 1935), and Haury (1937, 1976). The pace of irrigation studies, however, has increased over the past two decades. CRM projects such as the Salt-Gila Aqueduct survey and mitigation (Crown 1984a, 1984b, 1987a; Dart 1983a), the East Maricopa Floodway project and other studies near Gila Butte (Brooks and Vivian 1978; Howard and Rice 1982; Motsinger 1993; Rice et al. 1979), surveys on the Gila River Indian Community (GRIC; e.g., Gregory and Huckleberry 1994), and the Grewe Archaeological Research Project (Phillips and Craig 2001), in addition to research projects on river geomorphology (Huckleberry 1995a) and streamflow reconstructions (Graybill 1999), have built on the earlier studies and provided a wealth of new information on irrigation agriculture in the middle Gila Valley.

Over the past eight years the GRIC Cultural Resource Management Program has been conducting archaeological, geological, and environmental investigations throughout the GRIC in conjunction with the Pima-Maricopa Irrigation Project (P-MIP). The P-MIP is administered by the GRIC with partial funding from the Bureau of Reclamation. A significant component of this research is focused on prehistoric canal irrigation in the middle Gila Valley (Woodson 2002). Studies that have been undertaken as part of this effort include geological mapping of the middle Gila Valley (Waters 1996; Waters and Ravesloot 2000); extensive block surveys across the reservation (e.g., Neily, Broyles, Brodbeck, James, and Touchin 1999; Neily, Randolph, James, and Brodbeck 2000; Woodson and Davis 2001); detailed mapping of surficial canal alignments and settlements in the Gila Butte–Snaketown area (Neily Randolph, James, and Brodbeck 2000; Woodson, Neily, and Raavesloot 1999); documentation of buried canal alignments heading on both the Gila River (Foster 2000; Woodson and Morgan 2001; Woodson and Randolph 2000) and the Salt River (Woodson and Neily 1998); reconstructions of Hohokam canal environmental and technological histories based on canal sediment analyses (Woodson and Neily 1998); analysis of modern canal and environmental samples from the GRIC as a basis for interpretation of prehistoric canal samples (Adams, Smith, and Palacios-Fest 2001); and the effects of landscape change on irrigation agriculture and Hohokam cultural evolution (Waters and Ravesloot 2001; Woodson and Davis 2001).

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[2] Some disagreement exists as to whether the seventh canal system, Midvale's (1963, 1965) Canal Pinal, was actually part of the Casa Grande canal system (Crown 1984a:220).

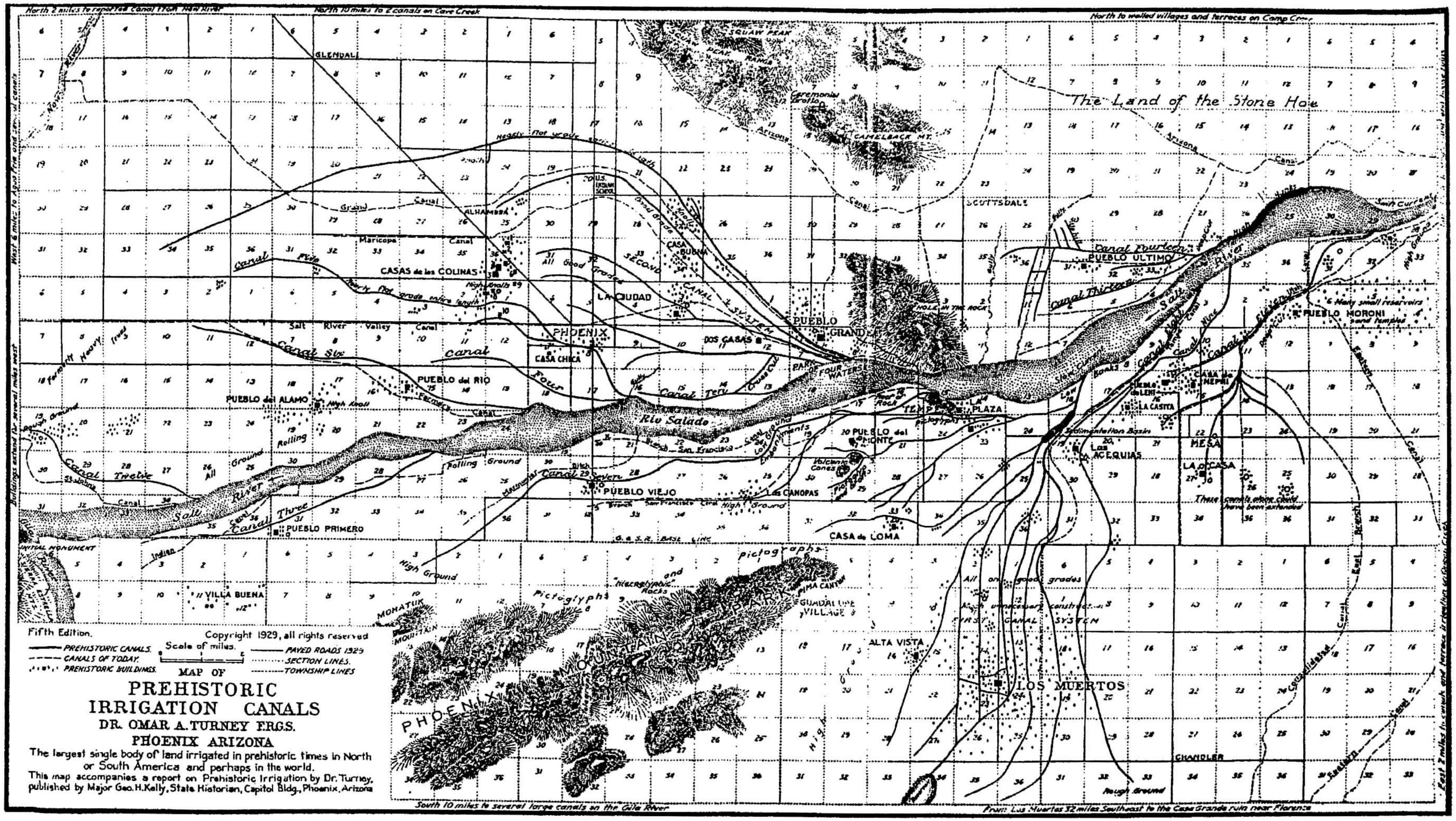


Figure 5.3. Omar Turney's 1929 map of canal systems in the Salt River valley.

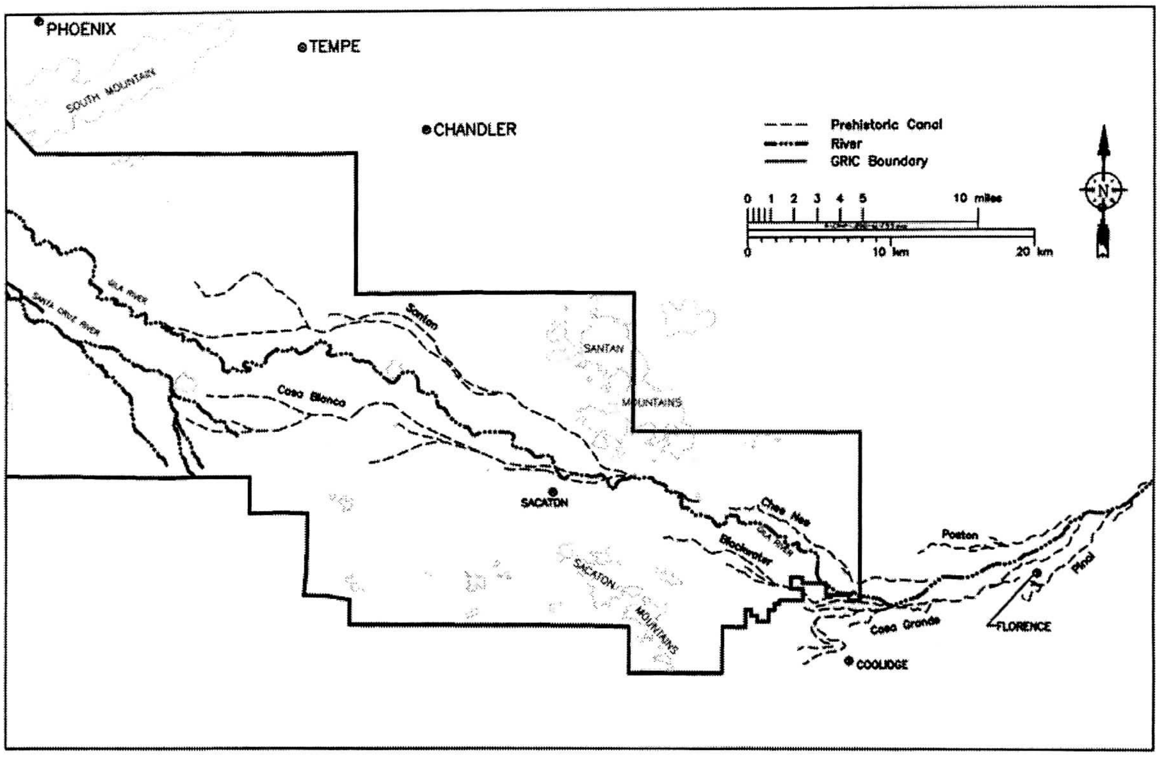


Figure 5.4. Prehistoric Hohokam canal systems along the middle Gila River.

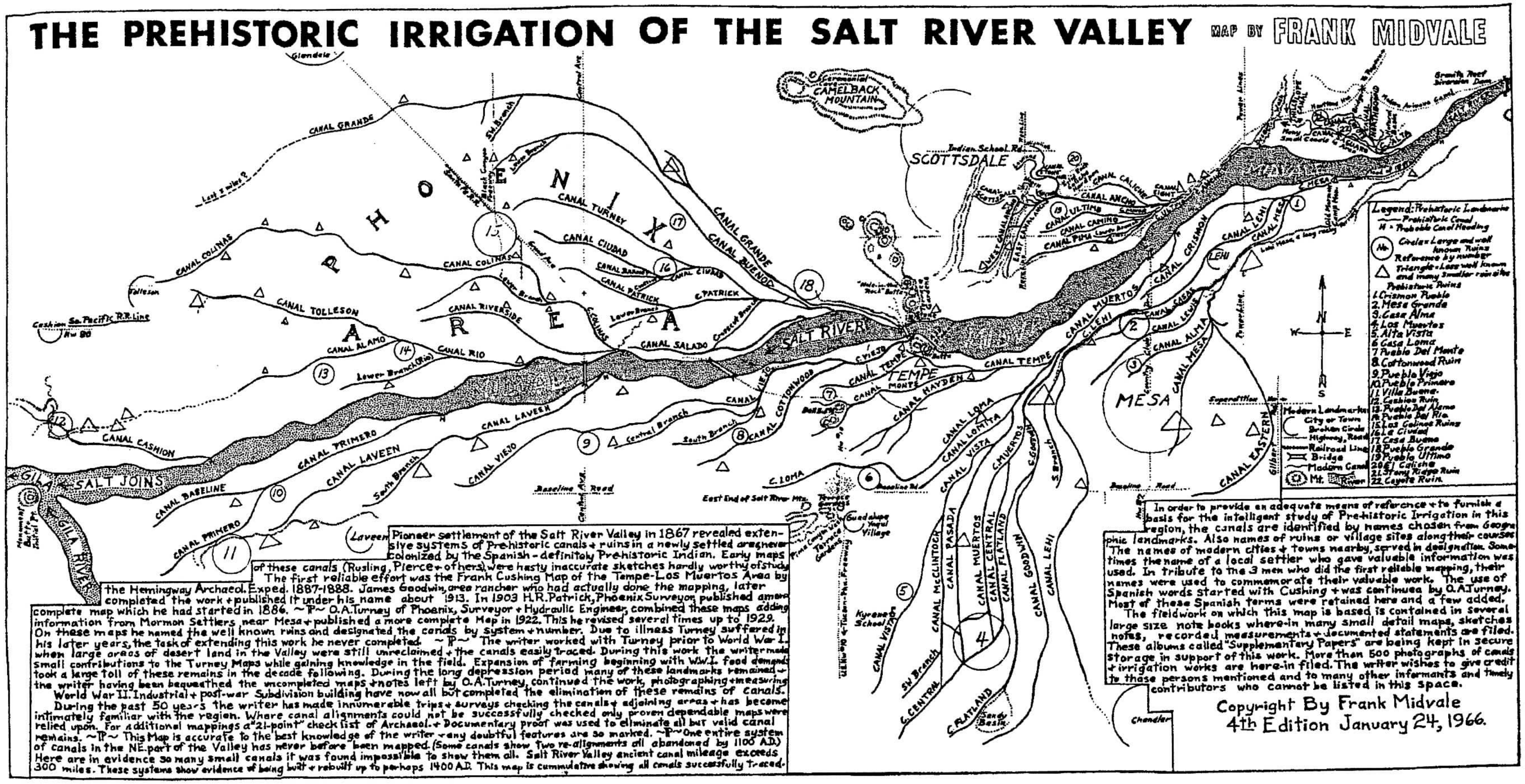
Queen Creek

Between the Salt and Gila rivers lies Queen Creek, a major wash that terminates in a delta in the middle Gila Valley. Five water-harvesting systems utilizing canals have been documented along Queen Creek (Brooks and Vivian 1978; Dart 1983a, 1986a; Crown 1984a; Turney 1929; Figure 5.6). These five canal systems constitute the longest canals and largest amount of land subjected to water harvesting known in North America (Doolittle 2000:335). In addition, three reservoirs also were found and excavated along these canal systems (Dart 1983a; Crown 1984a).

Agua Fria River and New River

At least five prehistoric canals have been identified in water-harvesting systems along the Agua Fria River, an intermittent stream that joins the Gila River about 6 miles downstream from the confluence of the Salt and Gila rivers (Dart 1989:13). Most of these canals were built by the Hohokam along the lower Agua Fria River (Dove 1977; Midvale 1971; Turney 1929). However, one canal was found along the upper Agua Fria River near Prescott (Weed and Ward 1970).

Canals also are found as part of Hohokam water-harvesting systems along New River, the largest tributary of the Agua Fria. Several canals were documented in the New River Gap area (Figure 5.7), and others were located farther north (Doyel 1984, 1985; Doyel and Elson 1985; Rankin and Katzer 1989; Midvale 1969, 1971; Turney 1929).



Pioneer settlement of the Salt River Valley in 1867 revealed extensive systems of Prehistoric canals + ruins in a newly settled area never colonized by the Spanish - definitely Prehistoric Indian. Early maps of these canals (Rusling, Pierce + others) were hasty inaccurate sketches hardly worthy of study. The first reliable effort was the Frank Cushing Map of the Tempe-Los Muertos Area by the Hemingway Archaeol. Exped. 1887-1888. James Goodwin, area rancher who had actually done the mapping, later completed the work + published it under his name about 1913. In 1903 H.R.Patrick, Phoenix Surveyor, published a more complete map which he had started in 1886. ~℗~ O.A.Turney of Phoenix, Surveyor + Hydraulic Engineer, combined these maps adding information from Mormon Settlers near Mesa + published a more complete Map in 1922. This he revised several times up to 1929. On these maps he named the well known ruins and designated the canals by system + number. Due to illness Turney suffered in his later years, the task of extending this work he never completed. ~℗~ The writer worked with Turney prior to World War I. when large areas of desert land in the Valley were still unreclaimed + the canals easily traced. During this work the writer made small contributions to the Turney Maps while gaining knowledge in the field. Expansion of farming beginning with W.W.I. food demands took a large toll of these remains in the decade following. During the long depression period many of these landmarks remained + the writer having been bequeathed the uncompleted maps + notes left by O.A.Turney, continued the work, photographing + measuring.

World War II. Industrial + post-war Subdivision building have now all but completed the elimination of these remains of canals.

During the past 50 years the writer has made innumerable trips + surveys checking the canals + adjoining areas + has become intimately familiar with the region. Where canal alignments could not be successfully checked only proven dependable maps were relied upon. For additional mappings a "21-point" check list of Archaeol. + Documentary proof was used to eliminate all but valid canal remains. ~℗~ This Map is accurate to the best knowledge of the writer + any doubtful features are so marked. ~℗~ One entire system of canals in the NE. part of the Valley has never before been mapped. (Some canals show two re-alignments all abandoned by 1100 A.D.) Here are in evidence so many small canals it was found impossible to show them all. Salt River Valley ancient canal mileage exceeds 300 miles. These systems show evidence of being built + rebuilt up to perhaps 1400 A.D. This map is cummulative showing all canals successfully traced.

In order to provide an adequate means of reference + to furnish a basis for the intelligent study of Pre-historic Irrigation in this region, the canals are identified by names chosen from Geographic landmarks. Also names of ruins or village sites along their courses. The names of modern cities + towns nearby, served in designation. Sometimes the name of a local settler who gave valuable information was used. In tribute to the 3 men who did the first reliable mapping, their names were used to commemorate their valuable work. The use of Spanish words started with Cushing + was continued by O.A.Turney. Most of these Spanish terms were retained here and a few added.

The fieldwork on which this map is based is contained in several large size note books where-in many small detail maps, sketches notes, recorded measurements + documented statements are filed. These albums called "Supplementary Papers" are being kept in secure storage in support of this work. More than 500 photographs of canals + irrigation works are here-in filed. The writer wishes to give credit to those persons mentioned and to many other informants and timely contributors who cannot be listed in this space.

Copyright By Frank Midvale
4th Edition January 24, 1966.

Figure 5.5. Frank Midvale's 1963 map of Hohokam canal systems and sites near Casa Grande National Monument (courtesy of Arizona State University).

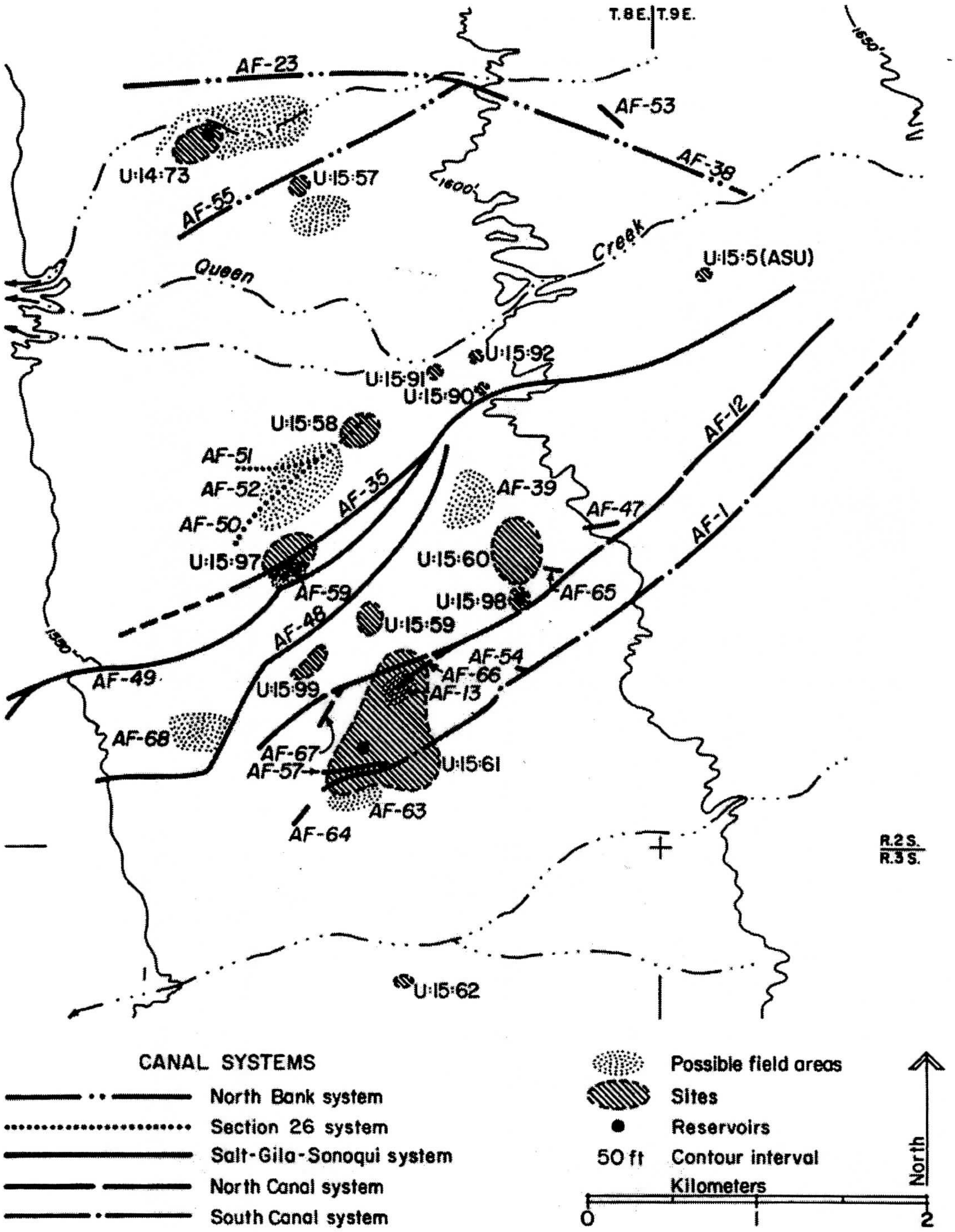


Figure 5.6. Map of Hohokam canal systems, water-management features, and sites along Queen Creek (from Dart 1983a:368).

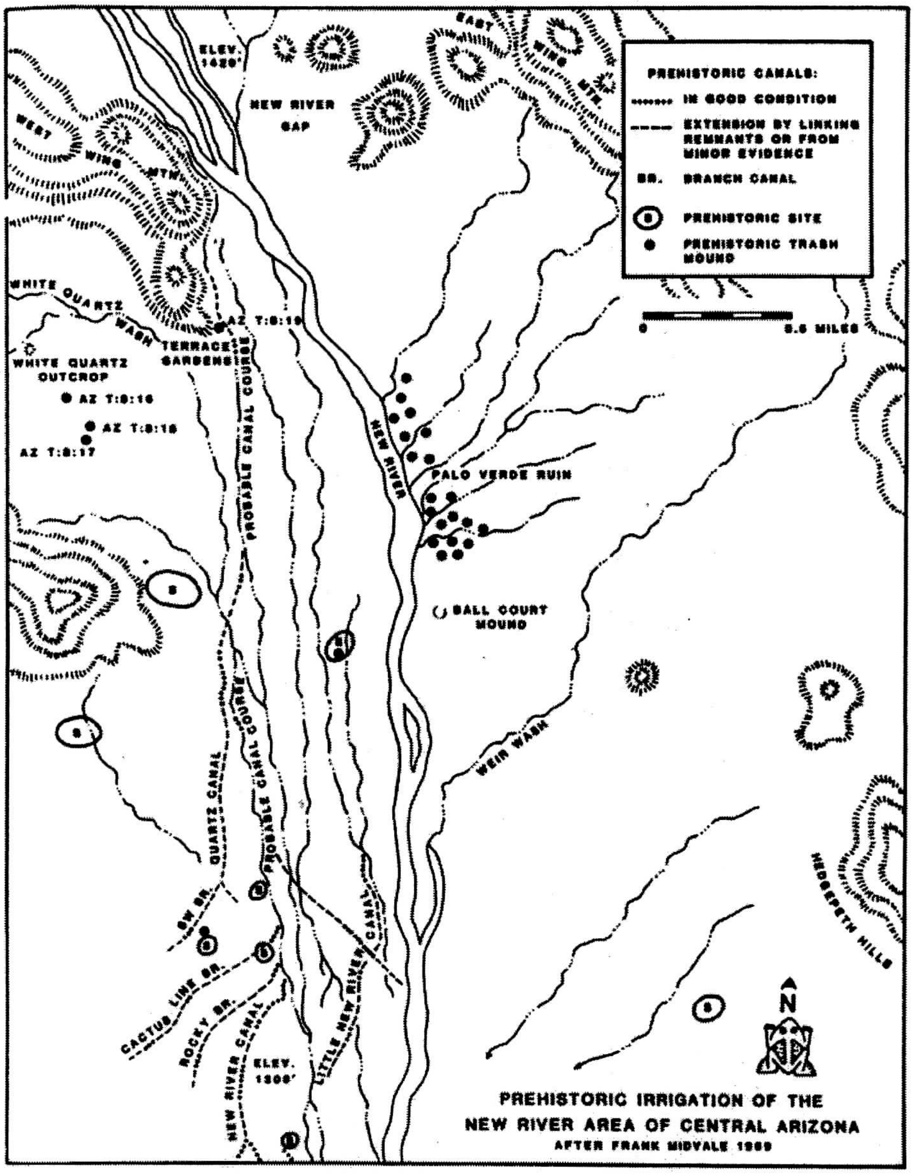


Figure 5.7. Prehistoric canals south of the New River Gap, in the Agua Fria River drainage, lower Salt Valley (from Doyel 1985:695; courtesy of Soil Systems, Inc.).

Lower Gila Valley

Hohokam canal systems also are found west of the Phoenix Basin in the Gila Bend area of the lower Gila Valley. Canals have been documented near Hohokam ballcourt villages such as the Gila Bend/Gatlin and Twelve-Mile sites, and others are thought to exist in the floodplain of this area (Dart, Lekson, and Wallace 1989; Doyel 2001; Midvale 1970, 1971, 1974; Rodgers 1976; Turney 1929; Wasley and Johnson 1965).

Verde Valley

A number of canals have been reported in the Lower Verde Valley, including Hohokam canals documented just above the confluence of the Verde and Salt Rivers (Canouts 1975; Hagenstad 1969; Midvale 1971). In the Horseshoe Reservoir area, three canal systems have been documented (Midvale 1946, 1971; Mindeleff 1896; Van West and Altschul 1997; Figure 5.8). Significantly, aqueducts were built at two wash crossings along the Limestone Creek Canal. These are two of only a few known prehistoric aqueducts in Arizona. A site south of Horseshoe Dam reportedly contains two other prehistoric canals (AZSite 2001; Dart 1989:11).

Sinagua canals have been identified in the floodplain of the upper Verde Valley near Camp Verde (Fewkes 1898; Mindeleff 1896) and Tuzigoot National Monument (Hartman 1976; Schroeder 1960). The northernmost canal along the upper Verde River was found near Perkinsville (Midvale 1971). Also, Sinagua water-harvesting systems with canals have been documented along Beaver Creek (P. Fish and S. Fish 1984; Schroeder 1960). The canal at Montezuma Well diverted water from a sink-hole lake (Midvale 1971; Schroeder 1958). Other canals have been observed near the mouth of West Clear Creek and possibly along Oak Creek near Courthouse Butte (Breternitz 1960; Fewkes 1898; Mindeleff 1896).

Tucson Basin and Vicinity

As mentioned above, the earliest known irrigation canals in North America were built during the Early Agricultural period in the floodplain of the middle Santa Cruz River in the Tucson area (Doolittle 2000:372; Mabry 2002; Muro 1998). However, there appears to have been a hiatus in the use of canal irrigation between this time and the advent of Hohokam groups in the Tucson Basin. Most of the currently known prehistoric canals in the middle Santa Cruz Valley were constructed between A.D. 950 and 1100 (Bernard-Shaw 1988, 1989; Fish, Fish, and Madsen 1985; Fish, Fish, and Madsen 1992; Mabry and Holmlund 1998:285). However, most of these canals were abandoned between A.D. 1050 and 1150 following downcutting of some segments of middle Santa Cruz River (Mabry and Holmlund 1998:287; Waters 1988; Waters and Ravesloot 2001:295). Limited irrigation occurred in the floodplain after this time, such as near the Marana platform mound community (Fish, Fish, and Madsen 1992). Also, a water-harvesting system with one canal was utilized on the alluvial fan around Marana (Fish, Fish, and Madsen 1985). However, canals were again abandoned at the end of the Hohokam occupation of the Tucson Basin, coincident with another episode of downcutting between A.D. 1410 and 1450 (Waters 1988; Waters and Ravesloot 2001:295). Later, at the time of Spanish contact, Kino and Manje reported that the Sobaipuri Indians were irrigating their fields in the middle Santa Cruz Valley (see Doelle 1984). It is not clear how long the Sobaipuri had used irrigation prior to the arrival of Kino.

Canals also have been reported elsewhere in the Santa Cruz Valley, but outside the Tucson Basin. A canal was reported near Picacho to the north of Tucson (AZ AA:6:2 [ASM]) (AZSite 2001). South of Tucson in the upper Santa Cruz Valley, possible canals were reported between Canoa and Otero and near Lochiel (AZ DD:8:42 and EE:10:6 [ASM]) (AZSite 2001). However, canal irrigation in and around the Tucson Basin appears to have been restricted primarily to the middle Santa Cruz Valley.

San Pedro Valley

As with the middle Santa Cruz Valley, Kino and Manje reported that the Sobaipuri Indians were also irrigating fields in the lower San Pedro Valley at the time of contact (see Doelle 1984). Again, the length of time these canals had been used prior to contact is unknown. However, no prehistoric canals have been discovered anywhere in the San Pedro Valley (Dart 1989:14; Masse

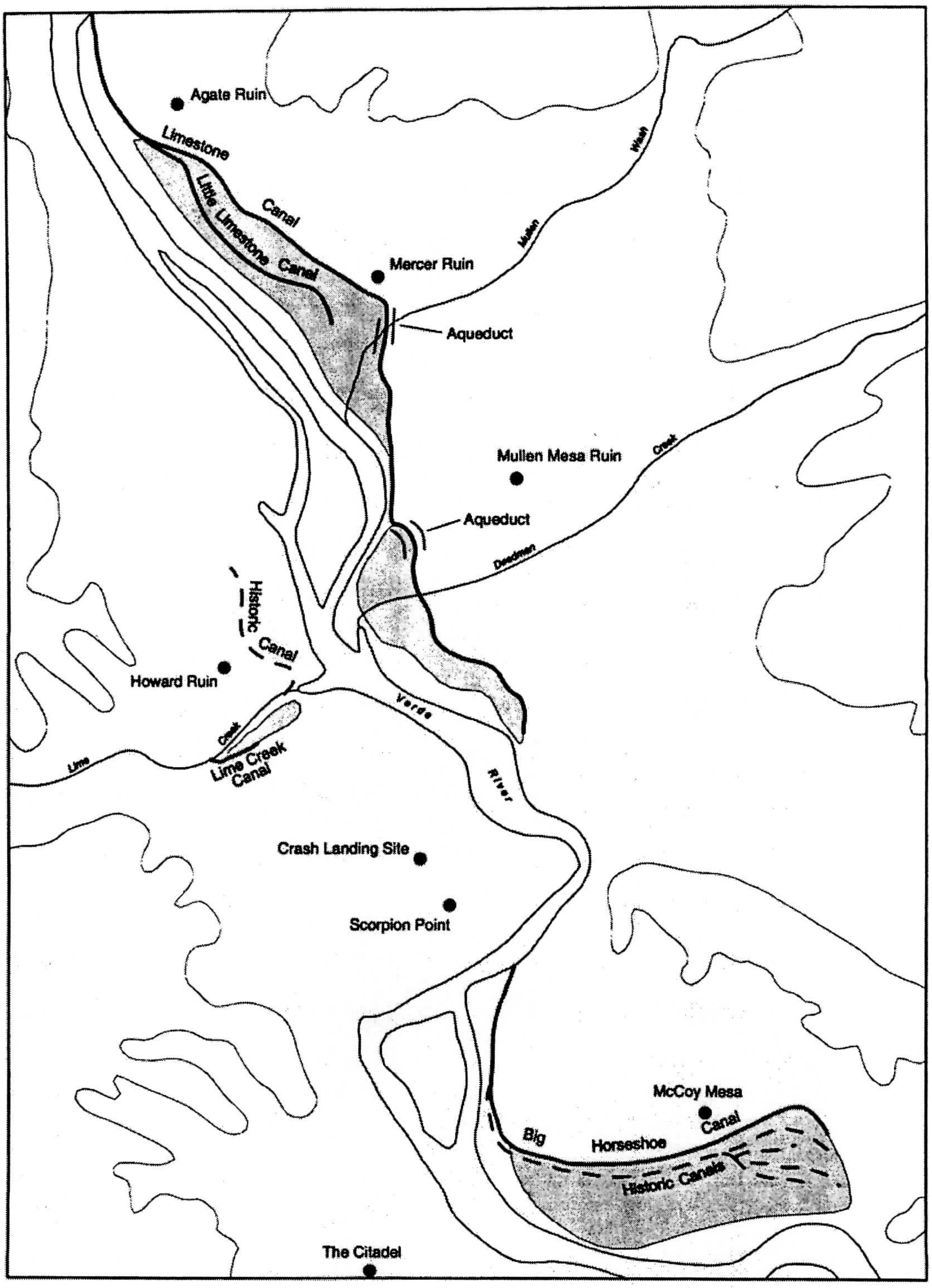


Figure 5.8. Schematic map of prehistoric canals, water-management features, and sites in the lower Verde Valley (from Ciolek-Torrello 1998:577; adapted from Midvale 1946, Van West et al. 1996; courtesy of Statistical Research, Inc.)

1980b). Regardless, it is assumed that the Hohokam or other prehistoric groups built canals in the relatively narrow river floodplain (Masse 1980b; Wallace and Doelle 1997). Unfortunately, the lack of archaeological excavations in the floodplain has prevented confirmation of this assumption.

Tonto Basin and Vicinity

Most of the known prehistoric canals in the Tonto Basin area emanate from the Salt River (Waters 1998:135–136). Several canals recently were investigated near the confluence of Pinto Creek and the Salt River during the Bureau of Reclamation–funded projects around Roosevelt Lake (Jacobs 1994; Waters 1998). In addition to these canals, Bandelier (1892) and much later Wood (1986) noted a canal near the Armour Ranch site complex on the north side of the Salt River. Tagg (1985) also reported that both Bandelier (1892:421) and Midvale (1964) mentioned the presence of prehistoric canals on the floodplain of the Salt River below Tonto Cliff Dwellings (see Waters 1998:136). Several potential prehistoric canals also have been reported along Tonto Creek. Waters (1998:136) notes the existence of a small canal near the Ewing Ranch, and he cites Scott Wood (personal communication 1994) as stating that a number of other possible prehistoric canals exist along Tonto Creek. Although much of the potentially irrigable lands in the Tonto Basin are now submerged and unavailable for research, canal irrigation clearly was practiced in the area on a limited scale. Notably, similar to the Tucson Basin and middle Gila Valley, the alluvial stratigraphy of the Salt River and Tonto Creek indicates that downcutting occurred at A.D. 1000, coincident with the Classic period transition (Waters 1998; Waters and Ravesloot 2001).

Two other canals have been noted east of the Tonto Basin along the Salt River. Bandelier (1892) reported a prehistoric canal near a pueblo ruin along Carrizo Creek near its confluence with Cedar Creek. Also, Wells (1971) reported at least one prehistoric canal, and some historic canals that may be reused prehistoric ones, in association with prehistoric sites along lower Cherry Creek. Irrigation canals may occur elsewhere along lower Cherry Creek as well.

Safford Basin and Vicinity

The Safford Basin includes the portion of the upper Gila Valley within Arizona above Coolidge Dam. The eastern basin encompasses the Safford Valley, and the western basin includes the upper Gila and San Carlos valleys in the area around San Carlos Reservoir. Few remnants of prehistoric canals along the river floodplain and terraces in the Safford Basin have been reported, and most of those reports were made during archaeological reconnaissance expeditions by Bandelier (1892), Fewkes (1904), Hough (1907), Sauer and Brand (1930), and Tuohy (1960). These individuals noted the presence of canals in various areas of the basin, although specific locations are not known for all of them. Canals were noted near present-day Fort Thomas (Bandelier 1892), and one was noted near the Buena Vista–Curtis site, east of Safford (Fewkes 1904:178; Haury 1984). Unfortunately, few archaeological excavations have been conducted in riverside portions of the Safford Basin where subsurface canals may still exist. However, two canals were recently discovered in the Safford area (Botsford and Kinkade 1993; Clark 2002). Prehistoric canals also have been documented in the San Carlos Valley along the San Carlos River (Mitchell 1986) and Gilson Wash (Bandelier 1892).

Despite the limited observations of canals along the rivers in the Safford Basin, it has been assumed that canals were quite common there in prehistory (Sauer and Brand 1930:422). A large number of prehistoric villages and habitations have been documented along the alluvial terraces of the upper Gila and San Carlos rivers by the archaeologists cited above as well as by later archaeologists (e.g., Black and Green 1995; Brown 1973; Johnson and Wasley 1966; see also Crary 1995). The occupants of these habitation sites, some of which exhibit Hohokam traits such as ballcourts, clearly were exploiting riverine subsistence sources, and it stands to reason that many of them were practicing canal irrigation. However, land leveling for agriculture and the construction of the San Carlos Reservoir have obliterated most of the surface evidence for canals in the basin. In addition, the lack of excavation projects conducted near the upper Gila and San Carlos rivers has prevented the identification of any subsurface remains of canals.

Prehistoric canals that were part of water-harvesting systems in the foothills, or bajadas, of the Pinaleño and Gila mountains were noted first by Bandelier (1892), Fewkes (1904), Turney (1929:157), and Sauer and Brand (1930). Archaeologists (Doolittle 2000:318–321; Neely 2001; Neely and Rinker 1997; Rinker 1998) recently have revisited and documented at least 10 "foothill" irrigation systems around the Pinaleño Mountains in Lefthand, Marijilda, and Taylor canyons and along Sand Wash. These water-harvesting systems diverted water from seasonally flowing mountain streams into rock-bordered canals, which distributed the water to a series of terraced and rock-bordered garden plots (Figure 5.9). Sauer and Brand (1930:434, 440) also found similar canals in the Sulphur Springs Valley on the bajadas of the Chiricahua Mountains, which are outside the Safford Basin in the southeastern corner of Arizona.

Little Colorado River and Tributaries

Prehistoric canals have been described in various areas along the Little Colorado River and its tributaries. Some of the first archaeological reconnaissances in the area reported canals along the upper Little Colorado near Springerville and St. Johns (Bandelier 1892; Danson 1957). As in the upper Verde Valley, some of these canals were fed by springs rather than streams (Bandelier 1892; Danson 1957). Further down the Little Colorado River, canals have been reported along Show Low Creek, Silver Creek, and Hay Hollow Draw, and irrigation is inferred along other parts of these streams (Lightfoot and Plog 1984). Canals also have been reported near Chavez Pass ruin along Jack's Canyon (Lightfoot and Plog 1984), and nearby at the Pershing site in Anderson Canyon (Fish, Pilles, and Fish 1980; McGregor 1958). Closer to Flagstaff, canals dating to the Pueblo I period were found along San Francisco Wash and Schultz Creek (Breternitz 1957a, 1957b; Pilles 1979). Irrigation has been inferred at the Ridge Ruin in Young's Canyon (Fish, Pilles, and Fish 1980).

Dart (1989:17) suggests that prehistoric irrigation may have been practiced along the Puerco and Zuni rivers and Moenkopi Wash. Earthen dams forming reservoirs may have been part of canal systems in areas drained by the Little Colorado River (see Lightfoot and Plog 1984). Thus, irrigation may have practiced where these features are found, such as at a site along the Puerco River (Dart 1989:17). Historically, irrigation was used along the Zuni River, thus it may also have used during Prehistoric Puebloan times (Dart 1989:17; Kintigh 1984).

Colorado River and Minor Tributaries

No direct evidence of prehistoric canals has been found along any part of the Colorado River or its minor tributaries in Arizona. As Dart (1989) suggests,

> Indeed, irrigation was probably impossible along the part of this river above the Grand Canyon, because the flow was too fast to control and the river was too far below the level of the surrounding plains for water to have been diverted. Below the Grand Canyon most of the river's wide flood plain is so deeply inundated by flooding every year than Indians could have raised a crop using only the water retained in the ground after floods; this would have made irrigation unnecessary along the lower Colorado [Dart 1989:18].

However, Schwartz (1956) speculated that irrigation may have allowed a population increase along Cataract Creek, a tributary of Havasu Creek, as evidenced by a large increase in sites in the area.

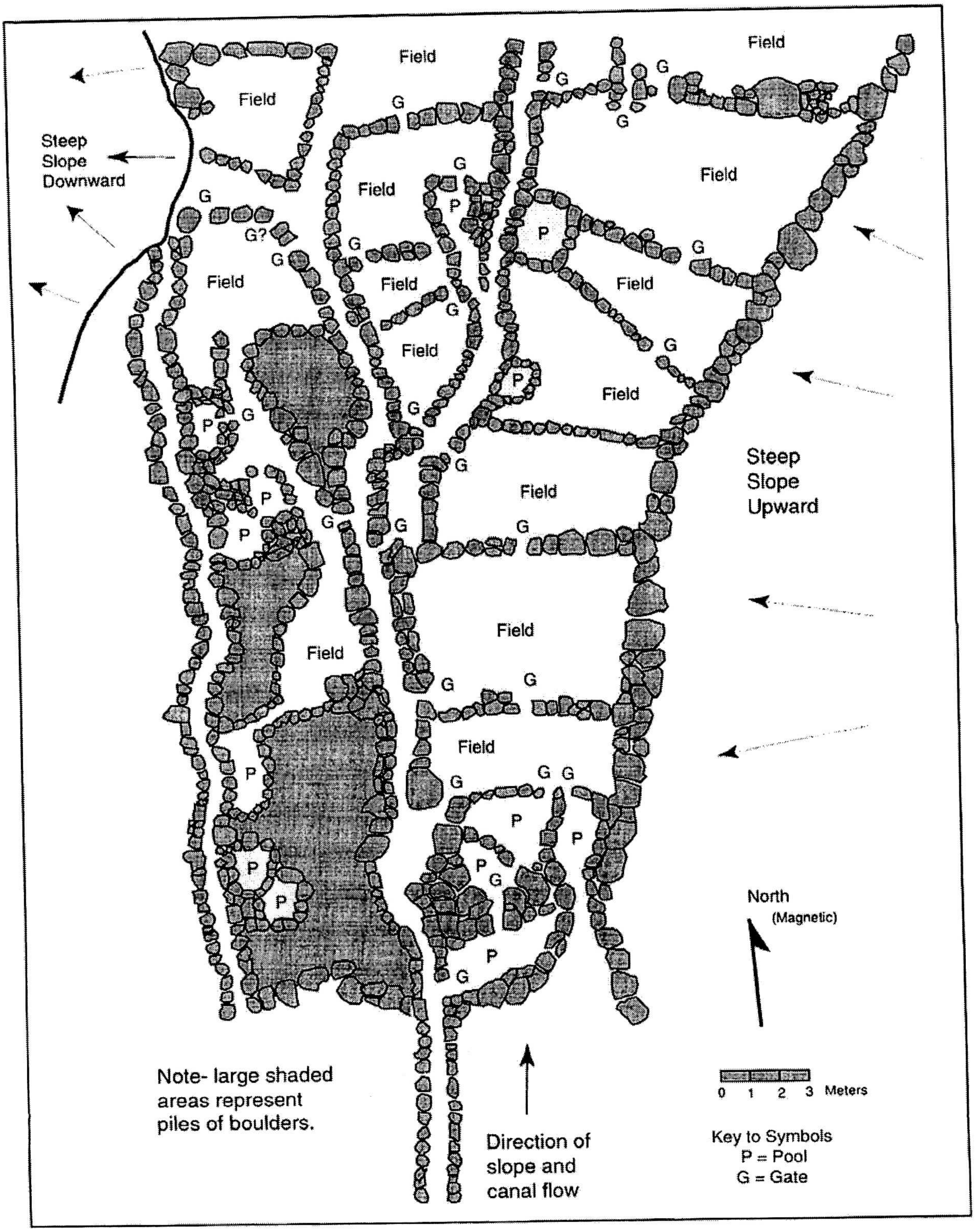


Figure 5.9. Map of a portion of a foothill irrigation system on the northern *bajada* of the Pinaleño Mountains in the Safford Valley (from Doolittle 2000:320; courtesy of James Neely).

Papaguería

The Papaguería, the homeland of the Tohono O'odham (Papago) Indians, is that area bordered roughly by the Gila River on the north, Altar Wash and the Baboquivari Mountains on the southeast, and the town of Ajo on the west (Dart 1989:18). The prehistoric canals in this area most likely were built by the Hohokam or a similar cultural group as components of water-harvesting systems. These canals emanated from seasonally active washes, such as between Vamori and Fresnal washes north of Valshni Village (Withers 1973), and along Sells Wash (AZSite 2001), Anegam Wash (Masse 1980a; Raab 1975), Greene Wash (AZSite 2001), and an unnamed tributary of Midway Wash (AZSite 2001). Also, canals probably fed prehistoric reservoirs along Santa Rosa Wash and between Gu Achi and Anegam washes (Masse 1980a; Raab 1975).

PROPERTY TYPES ASSOCIATED WITH CANAL IRRIGATION SYSTEMS

A plethora of terms have been used over the years by archaeologists to define features associated with prehistoric canal irrigation systems (Doolittle 1990:11–17; Rankin and Katzer 1989). As a result of recent attempts to standardize terminology (e.g., Breternitz 1991; Doolittle 1990; Howard and Huckleberry 1991; Masse 1991a; Nials and Gregory 1989), standard hydraulic engineering terms are now commonly used to describe irrigation features in the Southwest. The basic components, or property types, associated with canal irrigation systems are described in this section. Figure 5.10 is a schematic representation of the major components of a Hohokam irrigation system in the lower Salt Valley (after Masse 1991b). Although variations are found in different parts of Arizona, these basic elements characterize all canal systems, the principal features of a which may be grouped into three sections: headwater or intake, canal, and field features (Doolittle 1990:13–17). In addition, other water-utilization features, such as reservoirs and settling basins, may be associated with canal systems.

Headwater Features

Structures for capturing and diverting stream flow are found at the head, or headwater, section of the canal system. In the archaeological literature of Arizona, this is often cited as the intake. No permanent intake structures are known to exist in prehistoric canal systems in Arizona. Thus, it is assumed that canal intakes built by the Hohokam probably resembled early historic canal intake structures (Nials and Gregory 1989:51), which were constructed of brush, logs, earth, and stone. Intake structures in other areas of prehistoric Arizona probably were similar in construction. The most common canal intake structures used by historic indigenous and Euroamerican groups in Arizona were weirs and diversion dams (Castetter and Bell 1942). In situations where stream banks were not much higher than the water level, water would flow by gravity action into canals that simply were excavated deeper than the stream water level. Weirs, built of upright poles interwoven with bundles of brush, could be placed in the streambed to better divert streamflow into canals (Castetter and Bell 1942:159). Diversion dams, on the other hand, are designed "to raise the level of water to a height where it can empty into a canal" (Doolittle 1990:14) in cases where simple weir diversion is not sufficient. Both structure types were inherently fragile, required frequent maintenance, and were destroyed easily by high-magnitude floods (Doolittle 1990:14; Nials and Gregory 1989:48).

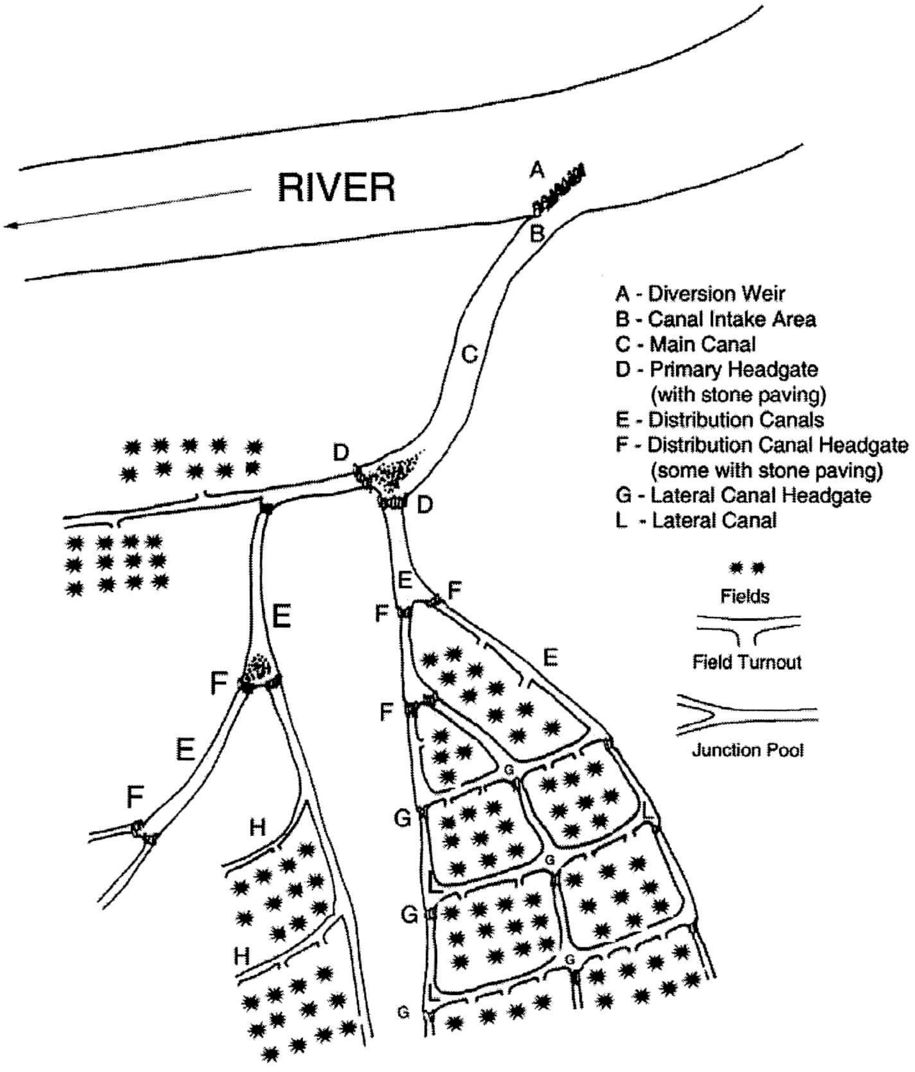


Figure 5.10. A schematic representation of the major components of Hohokam irrigation systems (after Masse 1991b, courtesy of Soil Systems, Inc.).

Similarly, the presumed impermanent construction of prehistoric intakes suggests a low degree of preservation. Indeed, only two examples of possible intake structures are known for all of the canal systems in Arizona (Dart 1989:19; Nials and Gregory 1989:51). Midavle (1971) reported that an early Euroamerican settler observed a line of "rocks the size of a stage coach" extending into the Salt River at the head of Midvale's Canal Mesa. Midavle (1971) noted another possible diversion dam remnant, aslo a group of large boulders, at the head of a prehistoric canal along Cave Creek.

Canal Features

Canals and their related features (e.g., head gates, diversion/sluice gates, erosion-control features, and aqueducts) comprise the "middle" section of a canal system and are by far the most common irrigation features found archaeologically in Arizona. Archaeologists generally recognize three canal types: main, distribution, and field lateral. A main canal conveys water from the intake to areas away from the stream or river. Distribution canals diverge from the main canal and carry water to the vicinity of fields. Field lateral canals transport water from a distribution canal directly onto the fields. Types are more easily assigned to canals in systems visible on the surface than to canals that are detectable only below ground surface. Theoretically, canal size (i.e., cross-sectional area) decreases from main to distribution to field lateral canals. However, canal size also decreases as distance from the canal head increases, so the tail of a main canal may be as small as a field lateral canal. In addition, canal dimensions can vary significantly within short distances along a given segment, depending on such factors as length of canal use (and re-use), extent of modification or repair, degree of preservation, and method of measurement (Nials and Gregory 1989:51–52). Thus, it can be misleading to assign canal types and estimate cross-sectional area and canal grade based on dimensions of a subsurface canal exposure. These problems can be alleviated somewhat by increasing the number of profiles exposed by trenching.

The regulation of water flowing through a canal system "requires the use of devices that can be opened and closed to varying degrees at each of the canals" (Doolittle 1990:15). Archaeologists generally have referred to such flow-management structures as head gates; however, geographers typically reserve the term "head gate" for structures at the far upstream end of a canal that are used to regulate the flow of water entering the main canal from the natural stream (see Adams 1976; Doolittle 1990:15). Head gates, in this sense, have not been documented in any canal systems in Arizona, probably because they were subject to the same destructive processes as intake structures. Diversion gates, also called sluice gates and gate structures, are structures at the junction of two canals or at a field turnout from a canal to a field (Nials and Gregory 1989:53). Evidence for prehistoric Hohokam sluice gates has been documented at several sites, such as Snaketown (Haury 1976) and La Ciudad (Ackerly, Howard, and McGuire 1987; Figures 5.11 and 5.12) in the lower Salt Valley, the Salt-Gila-Sonoqui canal system along Queen Creek (Dart 1983a), and Upper Santan in the middle Gila Valley (Foster 2000). Tapons are a type of sluice gate in lateral canals, probably composed of post-and-mat structures or slabs, used to dam the flow and raise the water level to facilitate diversion into field laterals, and subsequently into fields via field turnouts (Howard 1990; Masse 1991a:214; Nials and Gregory 1989:53). Field turnouts, simple openings cut into canal banks to allow water into fields, have been documented at some sites that contain surfice evidence of canals, such as in the Lehi canal system in the lower Salt Valley (Howard 1990:21–22) and the foothill irrigation systems in the Safford Valley (Neely 2001; see Figure 5.9). Significantly, drop structures, features used to move water from a higher elevation to a lower one, were not used by prehistoric irrigation agriculturalists in Arizona.

Without these, the amount of water that could be carried downslope and the distance to which it could be transported are limited by the degree of the landscape's contour (Nials and Gregory 1989:53).

A number of types of erosion-control and flow-management features were constructed to aid the operation of prehistoric canals. For example, bulges at canal junctions, known as plunge pools or junction pools, were built to slow water flow and retard erosion (Ackerly, Howard, and McGuire 1987:84–86; Masse 1987, 1991a:214). Some canal sections also were widened and deepened, apparently in an effort to reduce water flow and control erosion (Haury 1976:142; Masse 1987). Such areas also caused sediments to settle out of the water, reducing the amount of sediment that could clog the canal downstream from that point. Thus, such areas have been called "sedimentation basins"

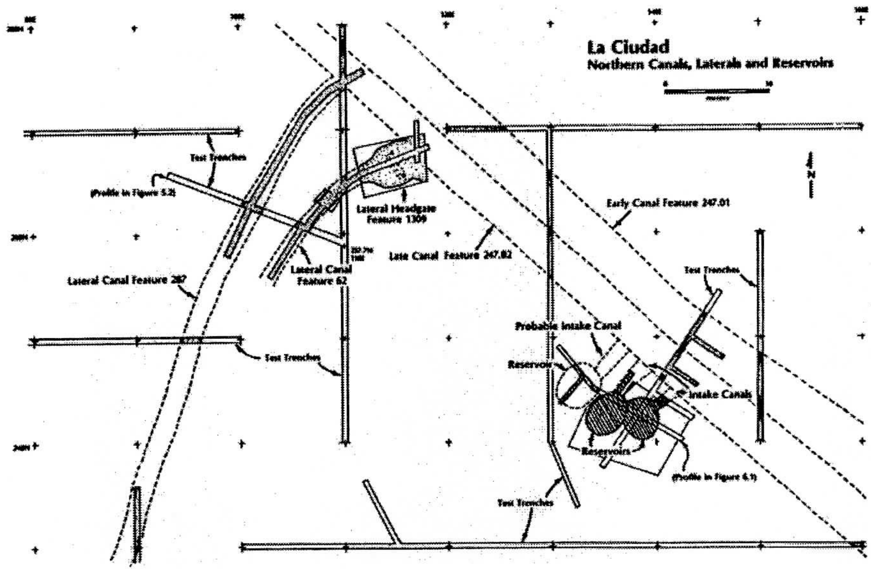


Figure 5.11. Map of La Ciudad northern main canals, lateral canals, and reservoirs in Canal System 2, lower Salt Valley (from Ackerly et al. 1987:80; courtesy of Glen Rice).

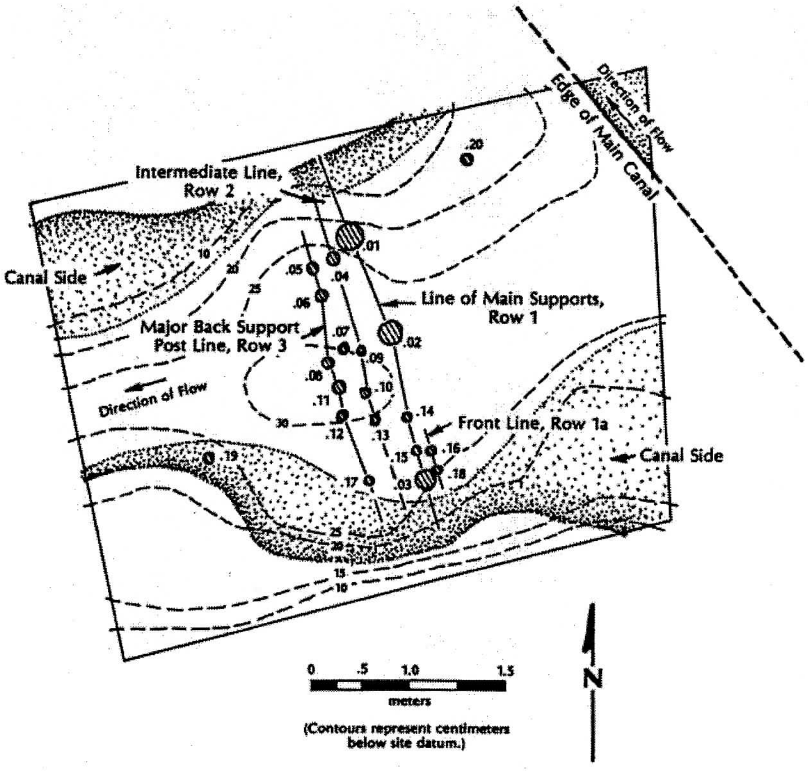


Figure 5.12. Map of lateral canal head gate area (Feature 1309) at La Ciudad in Canal System 2, lower Salt Valley (from Ackerly et al. 1987:85; courtesy of Glen Rice).

(Turney 1929). Rock alignments also may have been built across canal courses to serve as check dams to reduce erosion by slowing water flow (Dart 1989:29; Rodgers 1977). Cobble and artifact concentrations dumped in junction pools and other weak spots along canals served as "rip-rap" to strengthen areas prone to erosion (Ackerly, Howard, and McGuire 1987; Haury 1976). Canal edges sometimes were reinforced or repaired with rock and soil to repair ruptures or to prevent erosion at canal bends, areas at the bases of hillslopes, or intersections with small washes (Doyel and Elson 1985; Rankin and Katzer 1989; Rodgers 1977). An aqueduct is an elevated structure used to maintain an appropriate gradient for the flow of water over broad, low-lying areas or narrow but deep ravines (Doolittle 1990:15). Few prehistoric aqueducts are known in the state, but they include one along the Limestone Creek Canal on the lower Verde River (see Figure 5.10), a reported one in the lower Salt Valley (Patrick 1903), and a recently discovered one along the bajada of the Pinaleño Mountains in the Safford Valley (Neely 2001).

Finally, like historic earthen canals, prehistoric canal interiors required routine maintenance, which included cleaning out unwanted sediments and vegetation (Dart 1986b:64, 1989:29; Masse 1981; Nials and Gregory 1989:53–54; Woodbury 1960). Both suspended load (water-borne sediments) and sediments that washed in from canal banks tended to clog canals. These sediments were cleaned out and deposited along canal banks. Such clean-out episodes are manifested on the surface by unusual quantities of sediment along canal banks, and they are represented in canal profiles as unconformities in stratigraphy, multiple channels within canals, and the presence of sediments on and outside canal berms. Some canal sections were intentionally widened and deepened as a preventive measure to reduce suspended load and confine sediment accumulation. Haury (1976:135–136) also suggested that, after the recession of canal flow, some deepened areas could have served as "dipping pools". Vegetation within canals frequently was removed by burning (Hodge 1893; Masse 1981; Turney 1929). In profile, such burning is manifested by ash and charcoal zones or lenses and oxidized areas of sediment. Lastly, reconstructive maintenance necessitated by occurrences such as washouts and breaks in canal banks could be accomplished using measures similar to the erosion-control features described above.

Field Features

Field features comprise devices used to control the flow and distribution of water across the planting surface in a cultivated area (Doolittle 1990:15–16; Nials and Gregory 1989:41) and to demarcate field areas and garden plots. These features include bunds (earthen mounds constructed around the perimeter of a cultivated area), furrows, terraces (artificially leveled surfaces), and drainage ditches. Drainage ditches are used to collect excess water and transport it away from fields, and are thus differentiated from canals (Doolittle 1990:17). In irrigated areas where rock is abundant, various rock alignments and configurations may be used to construct field features. In such settings, preserved prehistoric field features may still be visible on the surface. For example, rock-constructed field features have been documented in canal systems along the bajadas of the Pinaleño Mountains in the Safford Valley (Doolittle 2000:318–321; Neely 2001; see Figure 5.9), on Beaver Creek in the upper Verde Valley (P. Fish and S. Fish 1984), the lower Verde Valley (Midvale 1946), and the Agua Fria and New rivers and Cave Creek in the Phoenix Basin (Doyel 1985; Midvale 1969, 1971; Rankin and Katzer 1989). In these small-scale canal systems, canals, field and garden borders, terraces, check dams, and diversion gates are often demarcated by rock alignments. Rocks sometimes are aligned in grid patterns and hence form waffle or gridded gardens. Gravel or cobble clusters, although more common in dry-farming fields, also are found in irrigated fields; these clusters may have served to retain moisture or may simply have been dumped during field clearing (Dart 1983a:404–410, 1989:31). Single boulders in prehistoric fields may have been used as boundary markers (Woodbury 1961b). Lastly, non-irrigation features such as field houses and artifact scatters commonly occur within or near agricultural fields (Crown 1983; Doyel 1985; P. Fish and S. Fish 1984; Lindauer 1984).

In irrigated areas where field features were constructed with soil rather than rock, various formation processes have obliterated most evidence of them. This is the case for Hohokam canal systems in the Phoenix Basin, as well as systems in other major rivers and streams such as in the Tucson Basin. Notably, however, Howard (1990:21–22) documented one exceptional case in the Lehi canal system in the lower Salt Valley, where a relict Hohokam field system is represented by a series of bunds perpendicular to a distribution canal and a field turnout. Despite the absence of visible field features in such areas, other methods may be used to identify fields (Crown 1984a:241–247; Dart 1989). Where canal networks, especially field lateral canals, can be traced and topographic parameters are known, investigators can infer that fields are situated below the level of lower-order canals. If rocks occur naturally along a canal system but were not used in field feature construction, areas that were intentionally cleared of rocks may represent fields (Crown 1984a; Lightfoot and Plog 1984). Sedimentological, pollen, and chemical analyses of soil from inferred field locations also may assist in the identification of field areas (Dart 1983a:527–547; Huckleberry 1992; Masse 1981:411). Comparisons with locations and traits of historically irrigated agricultural fields may provide useful analog data for evaluating the presence of prehistoric irrigated fields. Finally, field locations may be inferred by the presence of non-irrigation features such as field houses and certain artifact concentrations along alluvial terraces (e.g., Crown 1983; Lindauer 1984).

Other Associated Water Utilization Features

Other water utilization features associated with canal irrigation systems include reservoirs (Ackerly, Howard, and McGuire 1987:99–110; Bayham, Palacios-Fest, and Huckell 1997; Dart 1983a; Masse 1980a) and settling basins (Nials and Fish 1988). Reservoirs are pit features that stored water diverted from its original source (Crown 1984a:232), whereas settling basins are pits that served primarily to collect clay settled out of water diverted from a canal (Nials and Fish 1988). These features are distinguished from catchment basins and tinajas, which trap and store natural runoff and flood waters, and wells, which tap directly into the water table (see Chapter 4).

Canals that flowed through or terminated in prehistoric habitation sites could be used for drinking water and other domestic purposes (Haury 1976:135–136). Canals were routed into reservoirs at a number of Hohokam sites, such as La Ciudad (see Figure 5.11), Los Muertos, and AZ U:15:61(ASM) along Queen Creek (see Figure 5.6). Reservoirs also are found at Hohokam sites in non-riverine desert contexts (Bayman, Palacios-Fest, and Huckell 1997; Masse 1980a). Hohokam reservoirs range in size from around 4 m in diameter and 2.5 m in depth to around 70 m long, 40 m wide, and 4 m in depth. Most reservoirs have only a single inlet canal and no outlet canal (Ackerly, Howard, and McGuire 1987:109).

Two settling basins were identified at Las Colinas, along Canal System 2 in the lower Salt Valley (Nials and Fish 1988). These features are nearly identical in morphology to medium-sized reservoirs (roughly 20 m long, 15 m wide, and 4 m in depth) with a single inlet canal. However, other evidence suggests that the features functioned as settling basins for the procurement of clay in local pottery manufacture rather than as reservoirs (Abbott 2000; Nials and Fish 1988). For instance, the basins contained many sediments that were deposited while dry; no manganese or iron oxides were found at the base of the features; several wide, deep desiccation cracks were observed in the basin fill; and no aquatic flora or fauna characteristic of prolonged standing water were found in the basin sediments. Settling basins have not been identified at any other sites in the state. Perhaps such features truly are rare, however the dearth of features may be a result of a lack of intensive subsurface investigation, the uncritical evaluation of reservoir features, or the failure to conduct meticulous analyses necessary for identification.

DOCUMENTING RELICT CANAL SYSTEMS AND IRRIGATION FEATURES

The investigation of relict prehistoric canal systems and irrigation features may be envisioned as a process of discovery, documentation, analysis, and interpretation. As noted below, it is critical that archaeologists adopt a broad perspective in the study of irrigation features, integrating a wide range of environmental and cultural contextual data, to facilitate later interpretation. This section summarizes the techniques and criteria commonly used to locate and identify relict prehistoric irrigation features and collect basic field data and samples.

Locating and Identifying Relict Irrigation Features

A number of methods may be employed both before and during fieldwork activities to locate and identify relict canal systems and irrigation features in a given study area. Prior to the initiation of fieldwork, investigators should conduct research in the archives and site files of relevant institutions (e.g., SHPO, Arizona State Museum) as well as review pertinent literature to assess previous studies and previously recorded sites and features. Although this step is standard practice for most professional archaeologists involved in cultural resource management, it must be emphasized that a large amount of useful information previously has been compiled about prehistoric irrigation in Arizona. Of particular utility are the variety of maps available for most areas of the state. For example, site maps and maps of prehistoric canal systems (e.g., Howard and Huckleberry 1991; Midvale 1965, 1968, 1971; Turney 1929; see Figures 5.3 and 5.5) can provide significant baseline data for an investigation. Soil, geomorphic, and surficial geologic maps produced by state and federal agencies may be useful in helping to identify canal alignment locations (e.g., Dart 1986a; Waters 1996; Waters and Ravesloot 2000). In addition, the examination of historic and modern aerial photographs of a study area often is a productive method of identifying potential relict canal alignments and other irrigation features (Hackenberg 1974; Halseth 1932; Judd 1930, 1931; Masse 1981, 1991b; Figure 5.13). Other remote sensing sources such as satellite imagery also may be helpful in this task. Finally, one should not overlook researchers and local residents who are interested in the archaeology of a given study area as a valuable source of information. Potential relict irrigation features identified as a result of such research may be further inspected and documented during the fieldwork stage of investigation.

Field efforts to locate and identify relict canal systems and irrigation features may be discussed in terms of surface and subsurface methods. Basic pedestrian archaeological survey constitutes the most efficient surface field method for such tasks. Frank Midvale (1968:29–30), a tireless explorer and recorder of many ancient irrigation systems in Arizona, identified nine possible indicators of the course of a relict canal over an undisturbed surface. Dart (1989:22) reviewed and partially modified these criteria:

1. A canal segment that retains nearly the original contour (rarely seen)
2. A partly eroded remnant of the canal, with the area between the banks partly filled
3. A heavily eroded remnant of the canal, with the area between banks nearly filled
4. A long mound [or a low ridge, see Dart (1986)] marking the canal course, with the *actual canal* still buried in the approximate center of the mound
5. Two parallel zones of rock on the surface [sometimes associated with particular arrays of vegetation, see Dart (1983a:366, 387, 525–526); Rankin and Katzer (1989)
6. A wide path of ancient artifacts and debris across the desert
7. Rock-walled or slab-retained canals, usually small in size
8. A single dike or rubble wall opposing an even hillslope (the dike/wall marks the downhill bank of the canal)

9. A canal segment marked by a natural cement [caliche] lining caused by lime left behind when the water evaporated; examples of this type occur at Montezuma Well National Monument and in the Little Colorado River drainage (Bandelier 1892; Danson 1957:63; Midvale 1968, 1971)

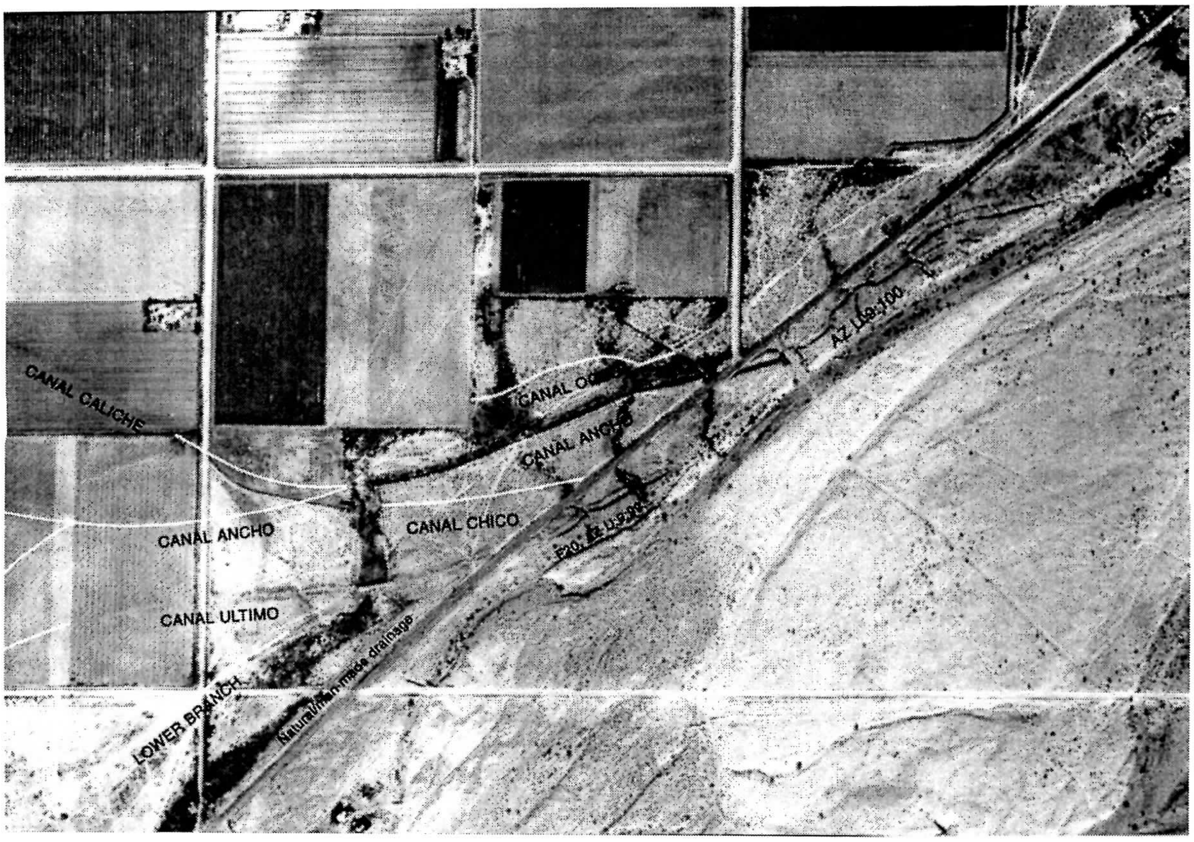


Figure 5.13. Aerial photograph of Hohokam canals in the Scottsdale canal system in the lower Salt Valley (from Hackbarth et al. 1995:9; courtesy of the Arizona Department of Transportation).

A few other surface field techniques are used to detect potential relict irrigation features. For example, use of geophysical prospecting equipment such as a magnetometer and ground penetrating radar may prove to be effective in detecting subsurface irrigation features (Conyers 1998, 1999). Also, low-elevation aerial photographs may be acquired to obtain more detailed coverage of a study area than offered in standard aerial photographs. Although these remote sensing techniques can be productive, the additional time and expense required may be prohibitive when compared with the more common archival and survey methods.

The location and identification of subsurface relict irrigation features is accomplished best by controlled archaeological excavation. Backhoe trenching has proven to be the most effective excavation technique in this task. In some cases, whether or not they are anticipated, irrigation features are encountered in the normal course of excavation projects. However, excavation strategies may be developed to target specific areas with a higher probability of containing canals and other irrigation features. Knowledge of the geomorphic and pedological (soil) setting can help guide excavation and facilitate recognition of subtle irrigation features. For example, canal alignments may be clustered near stream terrace boundaries due to slope constraints and efforts to maximize irrigable area. As a result, excavations should focus on areas near the top and base of the terrace scarp. Likewise, an understanding of regional hydrology and floodplain geometry can help to discern where canal headgates (long since destroyed) may likely have been placed, thus providing a guide to where downstream alignments are more likely to occur. As mentioned above, soil, geomorphic, and surficial geologic maps, maps of prehistoric canal systems, and aerial photographs may be useful in planning an excavation strategy to locate subsurface canals. Also, examination of exposed cutbanks and other eroded areas as well as previously excavated and disturbed locales can reveal evidence of subsurface canals.

Once a potential subsurface irrigation feature has been discovered, how does an investigator confidently identify it as a relict canal or other irrigation feature? The main identifying characteristic of a canal is the presence of a depression with a layer or successive layers of alluvial sediments (sands, silts, and clays). In cross section, prehistoric canals usually are U-shaped or V-shaped; however, canal shape can be quite variable (Ackerly and Henderson 1989; Ackerly, Howard, and McGuire1987; Dart 1983a; Hackbarth, Henderson, and Craig 1995; Haury 1976; Howard and Huckleberry 1991; Masse 1981). Some canals have flat bottoms, others are irregularly shaped, still others contain multiple channels of sometimes different shapes. Some canals that were buried by flood deposits still have intact berms. Also, the identification of a subsurface feature as a canal is bolstered if it exhibits any of the surface traits of canals identified by Midvale (1968), as listed above. Other irrigation features, such as reservoirs and settlement basins, also contain alluvial sediments, although they differ morphologically from canals.

In some cases, distinguishing between a canal and natural fluvial channel can be problematic (Ackerly 1995). Criteria for identifying a feature as a canal include (Ackerly 1995:285):

1. Showing that its course does not mimic the courses of natural drainages or arroyos
2. Trying, where possible, to show a clear physical connection between presumptive canals and the drainage from which water was obtained for the canals
3. Excavating a large enough number of cross-sections [three or four] to demonstrate that the feature is continuous over some distance
4. Completing hydraulic studies in sufficient detail to document sediment characteristics and channel gradients
5. Excavating sufficient quantities of canal sediments so that artifact content and other internal characteristics can be evaluated

In addition, it may be difficult to distinguish between prehistoric canalsand historic and modern examples. In the absence of artifacts, materials, or stratigraphic relationships that can be dated (see below), some morphological traits can be used as general distinctions. For instance, historic canals tend to be wider and deeper than prehistoric canals, and are trapezoidal rather than parabolic or U-shaped in cross section (Freeman 1995; Huckleberry 1991). Clay or iron and manganese minerals often settled out of the water and accumulated at the base of prehistoric canals, indicating waterlogged conditions in the canal (Freeman 1995). Prehistoric canals differ from modern canals, but not necessarily historic canals, in two other ways. First, prehistoric main canals generally branched at 45-degree angles, forming a leaf-like pattern (Masse 1981; Nials and Gregory 1989:55), in contrast to modern canals, which generally branch at right angles. Also, most prehistoric canals tend to meander, following the contours of the land in order to maintain a consistent drop in elevation (Nials and Gregory 1989:47). However, historic canals (both indigenous and Euroamerican) can be similar to prehistoric canals in these patterns; indeed, they often followed the same alignments of prehistoric canals (Turney 1929).

Basics of Data Collection

After a canal or irrigation feature has been located and identified, it must be sufficiently documented and sampled to facilitate an adequate interpretation and provide material for further analysis. The following guidelines can structure the effective collection of field data from relict canal systems and irrigation features.

Data Collection Strategies

Relict canal systems are mostly stratigraphic phenomena and require careful, methodical excavation, mapping, and description in the field. The first step in investigating a canal system is to locate the various main, distribution, and lateral canal alignments (Figure 5.14). Once canal alignments are identified, they need to be traced as far as possible with multiple cross sections for purposes of mapping and documenting any possible longitudinal (downstream) changes in channel geometry and stratigraphy. This is accomplished by excavating multiple trenches perpendicular to the axis of the canal alignment. As described in the sections below, excavated portions of canals and other features need to be described and sampled for further analysis. The elevation of the main channel should be surveyed to assess canal gradient. Finally, it is critical that canal intersections be investigated to determine the relative ages of the channels and locate water-control features, such as head gates.

For canal systems or irrigation features visible at ground surface (e.g., the Beaver Creek canal system in the upper Verde Valley and foothill irrigation systems in the Safford Valley), a great deal of data can be recovered by surface survey, description, and mapping, as well as aerial photography. Field areas and other irrigation features may be visible on the surface, too. In most cases, however, abandoned canal systems in Arizona are not visible at the surface, and they have to be revealed through excavation. For such subsurface irrigation features, some important data, such as the gradient of a canal alignment, can be collected from the surface. In either case, the excavation of canals and irrigation features is necessary to retrieve the maximum amount of information.

Excavation strategies vary with the specifics of the canal system or site under investigation, but all excavations should be designed to document canal alignment, stratigraphic relationships between canals and other archaeological features, and longitudinal variation in channel geometry. This may require either conventional trenching, or surface scraping to reveal the upper channel in plan view, or both. For irrigation features visible at ground surface, simple hand-dug trenches will be sufficient for such documentation. For subsurface irrigation features, a more intensive and likely extensive excavation strategy will be needed to locate and adequately document canals and related irrigation features. In the latter situation, as noted above, knowledge of the geomorphic, pedological, and hydrological settings can help an investigator select appropriate locations for excavation to locate canals. Once the alignment is well defined, efforts should be made to test for possible branching channels (laterals) by placing trenches adjacent to and parallel to the main channel. Finally, as mentioned above, effort should be given to the excavation and analysis of canal intersections.

Description

Profiles of canal stratigraphy should be made of vertical exposures perpendicular to the axis of the alignment to better define channel shape and area (Figure 5.15). Examples of canal profile drawings are depicted in Figures 5.16 and 5.17. Deposits both inside and outside the canal channel need to be described using U.S.D.A. soil nomenclature (Schoeneberger et al. 1998) and standard geological terminology for texture and bedforms (e.g., Boggs 1995). Geological approaches work well for characterizing fluvial bedforms, and pedological approaches are better suited for characterizing post-depositional alteration of canal sediments and possible irrigation impacts to adjacent soils. Profile description also should note the presence of unconformities in sediment deposition, which represent either natural or culturally induced modifications to canals or other irrigation features. Sedimentological features commonly documented in canal studies are listed in Table 5.2. In addition, when horizontal exposures are made of canals and related features, plan view drawings also should be completed after excavation (see Figures 5.11 and 5.12).

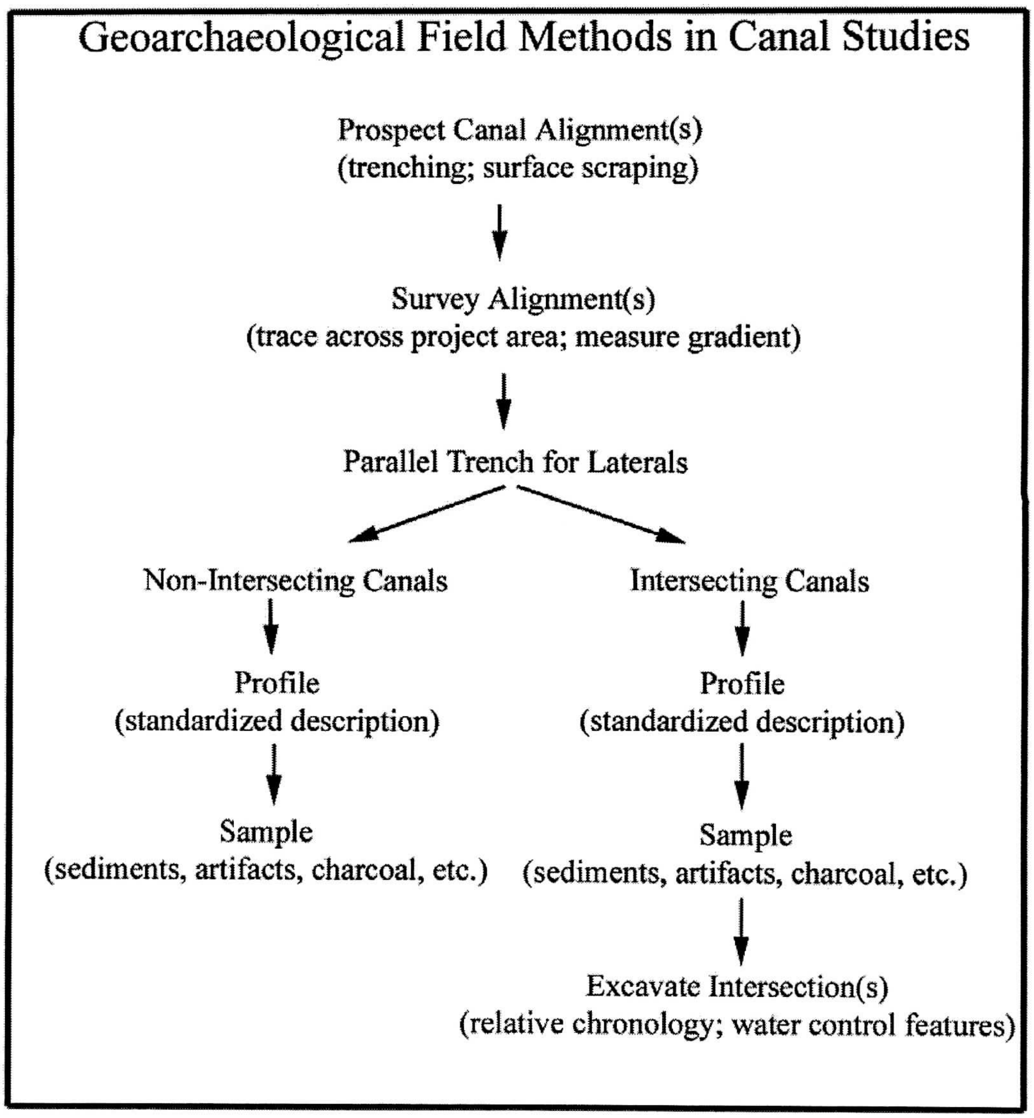


Figure 5.14. Geoarchaeological field methodology for documenting relict canals.

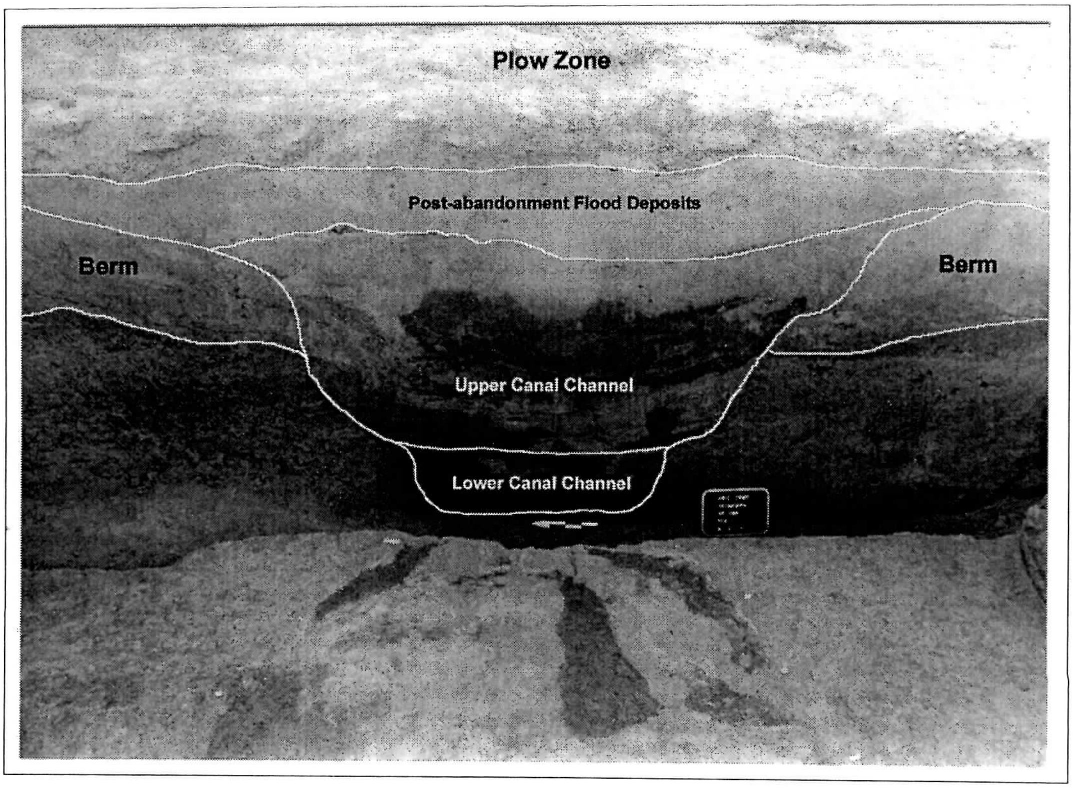


Figure 5.15. Photograph of trench exposure of a Hohokam main canal in the Santan canal system in the middle Gila Valley (from Woodson 2002; courtesy of the Cultural Resource Management Program, Gila River Indian Community).

Sample Collection

Canal deposits typically are sampled for various types of laboratory analyses. The number of profiles and number of samples per profile will vary with the circumstances at hand. Huckleberry (1991) provides guidelines for sampling canal sediments for granulometric analyses and characterization of depositional environments. The overall objective is to sample the stratigraphy that is characteristic of the feature (see Figure 5.17 for an example of a sediment sampling strategy). However, knowledge of sample context is critical, and this must be determined in the field. For instance, knowing whether a sample was taken from post-abandonment sediments in a canal or from canal sediments near a field lateral turnout will be important to later analysis and interpretation. If there are noticeable downstream changes, then more than one cross section should be profiled and sampled. It also may be instructive to sample sediments outside the channel for purposes of characterizing properties of the canal bank material and documenting possible irrigation impacts to adjacent soils. Sediments may also be sampled for various ecological analyses, including pollen, ostracode, and malacological (shell) studies (see Table 5.2).

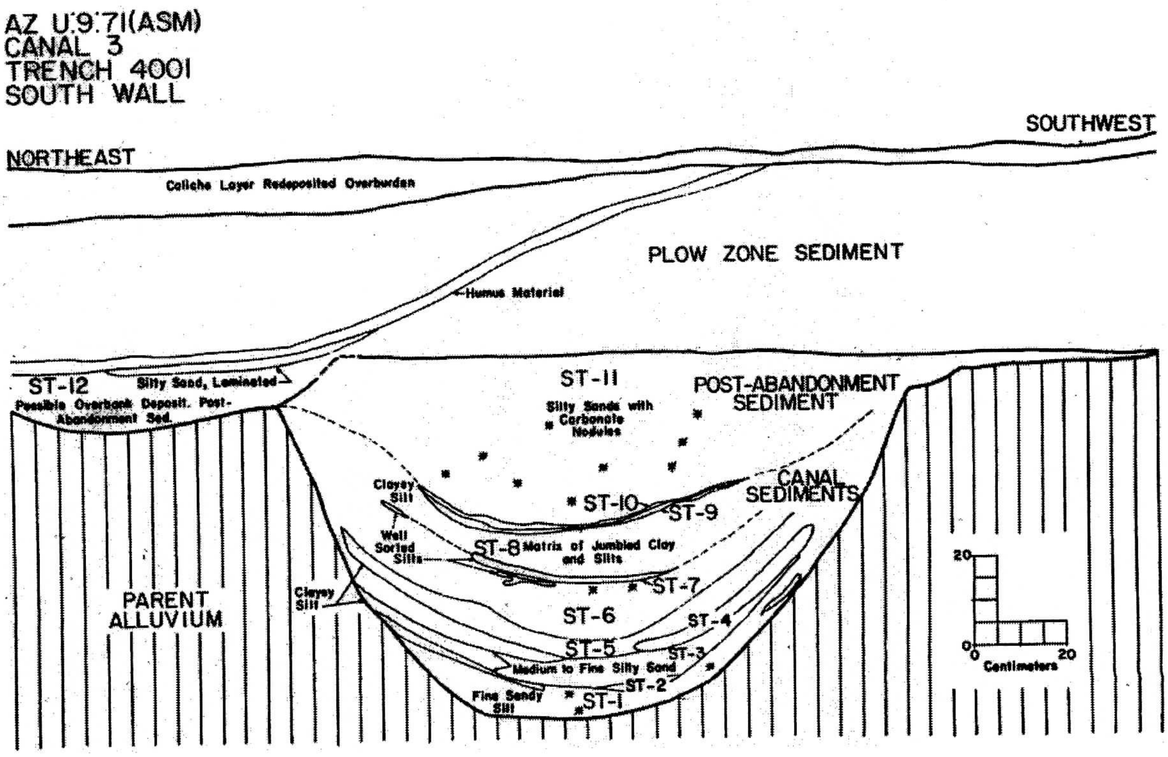
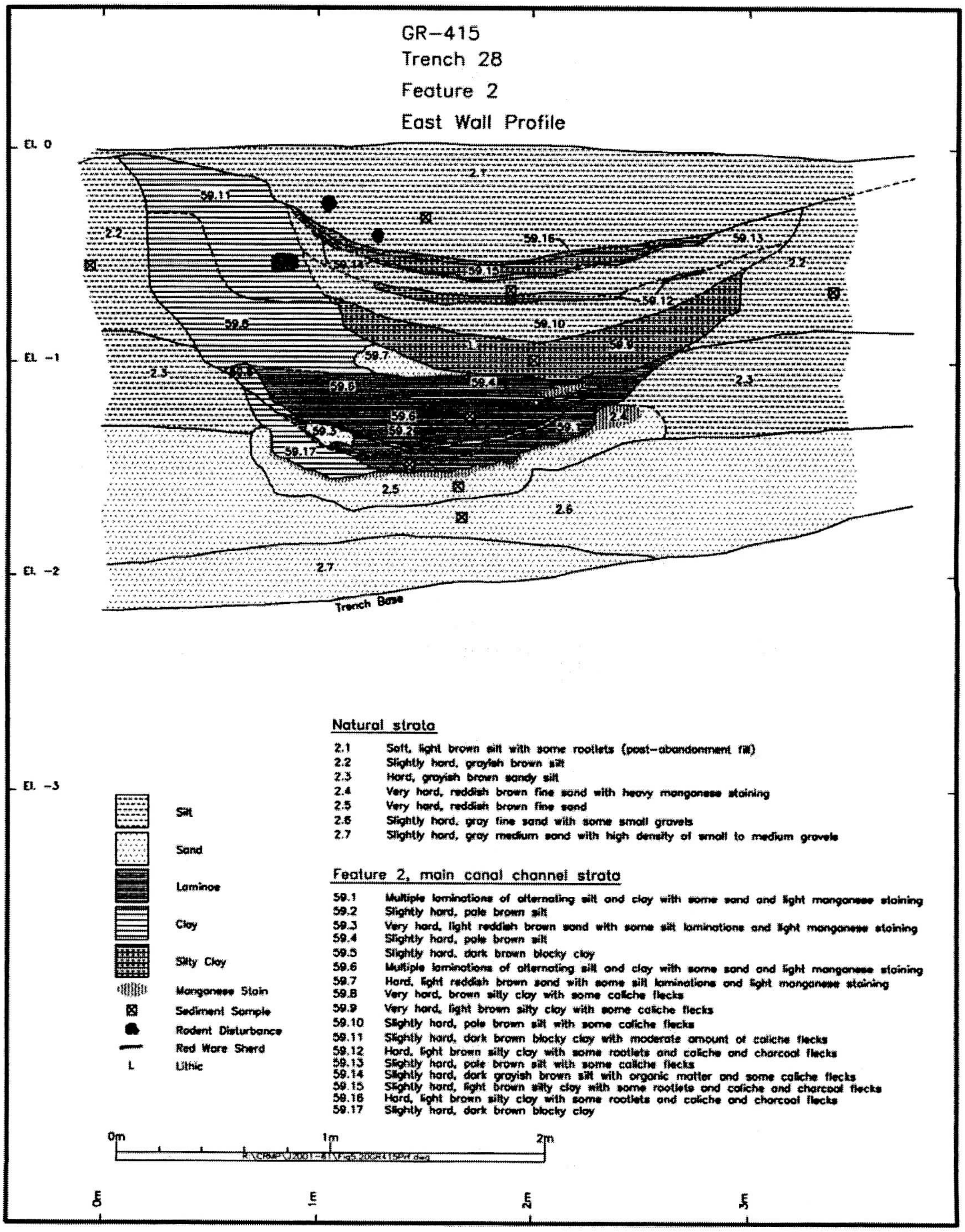


Figure 5.16. Profile of main canal from Las Acequias in the Los Muertos canal system (Canal System 1), in the lower Salt Valley (from Ackerly and Henderson 1989:137; courtesy of Northland Research, Inc.).

In addition to sediments, datable materials should be collected from canal and related deposits. Canals are notoriously difficult to date, at least at archaeologically significant timescales. Nonetheless, canals may contain organic materials that can be dated with radiocarbon (14C) techniques. The best material is fine charcoal associated with ash and concentrated in lenses. Other types of materials that can be radiocarbon-dated include individual pieces of wood and charcoal and bulk organic sediments. In addition, if fine-grained sediments such as silts and clays are present, these may be sampled for archaeomagnetic dating. Typically, a specialist will need to remove the sediment samples. Finally, some temporal inference can also be made by the artifact content of the canal. With prehistoric canals, this is likely to be ceramics, especially where canal segments are located adjacent to habitation areas. Recovering artifacts usually requires screening large amounts of canal sediment in order to retrieve an adequate sample, which ideally should be more than about 100 sherds.



Natural strata

2.1	Soft, light brown silt with some rootlets (post-abandonment fill)
2.2	Slightly hard, grayish brown silt
2.3	Hard, grayish brown sandy silt
2.4	Very hard, reddish brown fine sand with heavy manganese staining
2.5	Very hard, reddish brown fine sand
2.6	Slightly hard, gray fine sand with some small gravels
2.7	Slightly hard, gray medium sand with high density of small to medium gravels

Feature 2, main canal channel strata

59.1	Multiple laminations of alternating silt and clay with some sand and light manganese staining
59.2	Slightly hard, pale brown silt
59.3	Very hard, light reddish brown sand with some silt laminations and light manganese staining
59.4	Slightly hard, pale brown silt
59.5	Slightly hard, dark brown blocky clay
59.6	Multiple laminations of alternating silt and clay with some sand and light manganese staining
59.7	Hard, light reddish brown sand with some silt laminations and light manganese staining
59.8	Very hard, brown silty clay with some caliche flecks
59.9	Very hard, light brown silty clay with some caliche flecks
59.10	Slightly hard, pale brown silt with some caliche flecks
59.11	Slightly hard, dark brown blocky clay with moderate amount of caliche flecks
59.12	Hard, light brown silty clay with some rootlets and caliche and charcoal flecks
59.13	Slightly hard, pale brown silt with some caliche flecks
59.14	Slightly hard, dark grayish brown silt with organic matter and some caliche flecks
59.15	Slightly hard, light brown silty clay with some rootlets and caliche and charcoal flecks
59.16	Hard, light brown silty clay with some rootlets and caliche and charcoal flecks
59.17	Slightly hard, dark brown blocky clay

Figure 5.17. Profile of main canal in Casa Blanca canal system in the middle Gila Valley (from Woodson and Randolph 2000:232; courtesy of the Cultural Resource Management Program, Gila River Indian Community).

Table 5.2. Important Properties of Relict Canals to be Documented and/or Sampled.

Sedimentological Features (within and adjacent to canal feature)

Bedding (micro and macrostratigraphy)
Grain size
Mineralogy
Architecture (geometry of deposits)
Color and mottles
Structure (size, shape, and grade of soil aggregates)
Miscellaneous features (desiccation cracks, clay linings, salts)

Hydraulic Properties

Channel shape (width, depth, cross-sectional area)
Gradient

Ecological Contents

Pollen
Macrofossils (macrobotanical remains)
Ostracodes
Freshwater shell (mollusks)
Fish remains
Charcoal/Ash

ANALYZING RELICT CANAL SYSTEMS AND IRRIGATION FEATURES

Once field observational data and samples have been collected, an investigator may pursue a number of types of specialized analyses. The decision to proceed with such analyses will depend on the research goals of the project, but the most common methods are reviewed here.

Geoarchaeological Analyses

Despite the different designs and settings of irrigation systems, all canals are subject to the same physical laws that govern streamflow and sediment transport and deposition as occur in natural watercourses. Consequently, principles of open channel hydraulics, sedimentology, stratigraphy, and geomorphology can be applied to relict canal systems in an effort to better understand their history (Howard 1994; Huckleberry 1991). Together, these approaches provide a more holistic perspective of canal systems and generate baseline data from which higher-level research issues (e.g., cultural ecology and sociopolitical complexity) can be addressed (Howard 1994; Ortloff, Feldman, and Moseley 1985).

Stratigraphy is the study of the sequence and correlation of sediments and soils (Waters 1992:4), and the principle of superpositioning dictates that younger strata lie above older ones. This basic rule can assist in constructing a relative chronology of canal deposits and intersecting canals. Sedimentology, the study of the characteristics and formation of deposits (Waters 1992:4), can be used to help answer questions on the flow history and depositional regimes of canals (Huckleberry 1991, 1995a, 1995b). In this approach, laboratory particle-size analysis is used to characterize sediment components (silts, sands, clays) from canal sediment samples. Because alluvial textures record previous flow regimes (Huckleberry 1999a:8), there should be some correspondence between the reconstructed channel flow characteristics and transported sediments within the channel. Thus, for example, massive dark clay deposits in the base of a canal channel indicate stagnant water conditions (Freeman 1995). Conversely, high-energy, unregulated flood deposits in canals should be coarser than the underlying deposits formed by regulated canal discharge (Huckleberry 1999a, 1999b:28).

Hydraulic analysis of relict canals permits the reconstruction of water velocity and discharge, two important parameters for understanding irrigation capacity and channel stability (Howard and Huckleberry 1991; Ortloff, Feldman, and Moseley 1985). This type of analysis further helps to define the engineering efficiency of canals. That many modern canals follow the alignments of their prehistoric predecessors is a testament to the hydraulic efficiency of these systems. Paleohydraulic analysis provides more detailed evaluation of engineering efficiency by considering changes in water velocity and discharge in response to changes in channel shape and gradient at different points within a given system (e.g., Ackerly, Howard, and McGuire 1987; Busch, Rabb, and Busch 1976; Howard 1994). Such information also allows for an assessment of the amount of water that could be carried by these canals. Prehistoric and historic canals in Arizona were used mainly to grow crops, and thus defining these systems' irrigation capacities provides insight into the carrying capacity of specific irrigation communities. Although irrigation agriculturalists were skilled in combining floodwater, canal, and dry farming in their agricultural repertoire, in most riverine settings, they were heavily dependent on canals for the security of their food supply. Consequently, the hydraulic properties of relict canals in Arizona have been studied and related to potential irrigable area (e.g., Crown 1987a; Haury 1976; Howard 1994; Katzer 1989; Masse 1981; Mabry and Holmlund 1998; Nials, Gregory, and Graybill 1989). For a more detailed discussion of canal paleohydraulics, see Appendix A of this chapter.

Dating Prehistoric Canals

Several direct dating methods may be used to determine the age of a canal (Table 5.3). The two most commonly used chronometric techniques are radiocarbon and archaeomagnetic dating. The type of lens features best suited for radiocarbon dating have been associated with relict canals (Haury 1976; Masse 1981; Turney 1929) and likely represent in situ burning of weeds. Although individual pieces of wood and charcoal and bulk organic sediments can also provide numerical ages, they are more likely to yeild a greater discrepancy between the measured age and the actual age of the canal due to complex formation processes (Howard 1994). That is, an investigator often cannot be certain of the origin of materials that can be dated with 14C, hence, the association of the material with the canal frequently is ambiguous.

Table 5.3. Direct Dating Methods for Prehistoric Canals.

Relative Chronology
cross-cutting relationships with independently dated features (e.g. house floors, thermal features)
artifactual content (ceramics)
Numerical Chronology
^{14}C dating of in situ burns (concentrated charcoal and ash)
^{14}C dating of detrital wood and charcoal
^{14}C dating of organic sediment
archaeomagnetic dating

Another chronometric option is archaeomagnetic dating, especially if the canal contains silts and clays (Eighmy and Howard 1991). This method has provided reasonable age estimates for canals but requires a specialist to remove the sediment for laboratory analysis and has its own inherent range of potential error. For a more detailed discussion of the prospects for archaeomagnetic dating of canal sediments, see Appendix B of this chapter.

Some temporal inferences also can be made from artifacts recovered from canal contexts, particularly ceramics. An adequate sample of sherds increases the probability of estimating canal age. If a wide temporal range is represented in the ceramic sample, the stratigraphic context of the sherds may help differentiate different periods of canal use or modification based on the principle of superposition. Also, observations of ceramic abrasion and wear can help to determine whether the ceramics were emplaced during or after the operation of the canal (Ackerly, Howard, and McGuire 1987). Such an approach usually provides a maximum age estimate—for example, the canal is no older than a given ceramic age. In addition, a rough age of a canal system can be estimated based on the ages of archaeological sites associated with the system. However, this method can be problematic if the area was occupied for long periods of time and if the validity of association is unclear.

Where canals lack organic materials, fine-textured sediment, and artifacts in the fill, it may not be possible to obtain numerical ages. However, where canals intersect, relative canal ages can be provided by stratigraphic cross-cutting relationships. Such information allows for an analysis of canal system construction, remodeling, and expansion. Hence, it is critical that canal intersections be located and analyzed in order to determine the relative ages of the channels. Where intersections are contemporaneous, stratigraphy will be continuous, and efforts should be made to identify vestiges of water control features such as postholes and rock debris through excavation.

Analysis of Biological Organisms

The water in streams is full of aquatic life (fishes, mollusks, plants, and micro-organisms) and organic material, and these materials would have been swept into prehistoric canals that diverted stream water. During the operation of canal systems, as well as after their abandonment, plants (pollen and macrofossils [larger plant remains]) and micro-invertebrates (ostracodes and mollusks) become deposited in sediments within canals and associated features. Adams, Smith, and Palacios-Fest (2001) recently synthesized the insights gained from the numerous archaeological studies of Hohokam canal pollen (e.g., Bohrer 1970; Fish 1983, 1984; Gish 1989, 1991; Smith 1995), macrofossils (e.g., Miksicek 1983, 1989, 1995), and mollusks and ostracodes (e.g., Bayman, Palacios-Fest, and Huckell 1997; Miksicek 1989, 1995; Palacios-Fest 1994, 1997). Their review indicates that analysis of sediment samples for the remains of these organisms, coupled with sedimentological analysis, can provide information on several issues relevant to ancient irrigation agriculture (Table 5.4).

In some cases, micro-invertebrates alone provide insights, on the evolution of irrigation technology and on aspects of climatic change suggested by flood events or temperature changes. In other cases, pollen and macrofossils offer unique perspectives on aspects of canal construction components, distance of canal segments from river headwaters, burning of vegetation as a form of canal maintenance, nature of crops grown in agricultural fields, and wild plants likely encouraged along canals and the edges of nearby fields. Complementing each other, analysis of micro-invertebrates and pollen and other plant remains have revealed episodes of water flow in canals and periods of water stagnation or desiccation, have provided insight into season(s) of canal operation, and have proven useful in understanding long-term water storage in reservoirs. Micro-invertebrate and pollen data also are useful in datasets can help to differentiate irrigation features from other cultural remains. Regarding temporal trends, too few studies have been accomplished on micro-invertebrates and pollen to document clear-cut differences between pre-Classic and Classic period Hohokam canals.

INTERPRETING PREHISTORIC CANAL SYSTEMS AND IRRIGATION FEATURES WITHIN BROADER CONTEXTS

Although studying particular canal irrigation features involves meticulous field and laboratory work, investigators need to interpret these features within their broader environmental and cultural contexts (Masse 1991b). This analysis entails consideration of the geomorphological, climatic, hyrdrological, and edaphic contexts of canal systems and irrigation features, the formation processes that can modify irrigation features, and the cultural context of canals and irrigation features within larger subsistence-settlement systems.

Environmental Context

Canals are connected to the physical landscape, and their operation and productivity is affected by various characteristics (e.g., topography, soils, and hydrology) of that landscape. In turn, changes to that landscape undoubtedly affect canal system stability, and humans adapt to these changes by modifying their behavior. Proceeding from a wider perspective, geoarchaeological analysis provides a physical context for assessing the natural conditions and processes that influence (and are influenced by) canal construction, operation, abandonment, and preservation (Huckleberry 1991, 1995a; Waters 1992; Waters and Ravesloot 2000, 2001). Specifically, these data can be obtained from geomorphic landform maps, the alluvial stratigraphy of the water source for the canal system, dendrohydrological reconstructions of streamflow in the water source, and soil survey maps, as well as from canals themselves.

Of particular interest is the impact of climatic variability and how it may have influenced the development and operation of prehistoric agricultural systems in the Southwest. Modern distributions of plant and animal communities have largely existed for the last 4,000 to 5,000 years, but within this time there have been multidecadal to multicentury changes in moisture and temperature with environmental consequences (Sheppard et al. 1999). Of relevance to canal studies is the fact that arid fluvial systems are naturally dynamic and prone to dramatic changes in channel geometry due to both natural, internal adjustments and changes in flood regime (Ackerly, Howard, and McGuire 1987; Graf 1988; Waters and Ravesloot 2001). Because the frequency and magnitude of floods have changed over the last several thousand years (Ely et al. 1993), dynamic hydrological processes on alluvial fans and through-flowing rivers undoubtedly influenced how canal systems were constructed, operated, and maintained (Graybill 1999; Nials, Gregory, and Graybill 1989).

The earliest canal systems thus far identified in Arizona are located in the Tucson Basin, where small irrigation ditches that were used to collect streamflow in the Santa Cruz floodplain and on adjacent alluvial fans have been dated to 1000-500 B.C. (Ezzo and Deaver 1998; Mabry and Holmlund 1998). Stratigraphic studies of the Santa Cruz River floodplain and other rivers in southern Arizona suggest that these earliest canal systems were constructed during a period of overall floodplain stability. Huckell (1996) believes that this period of prolonged overbank deposition along the Santa Cruz and San Pedro rivers during the Early Agricultural period was conducive to early experimentation with water control and the eventual development of canal irrigation. Likewise, Huckleberry (1999c) and Waters and Ravesloot (2001) believe that the middle Gila River was relatively stable during this critical time of experimentation with water-control systems.

Table 5.4. Summary of Insights from Past Studies of Plant and Micro-Invertebrate Remains in Canals and Associated Features (from Adams et al. 2001:Table 3).

Topic of Study	Data Set(s)	Insights
Evolution of Irrigation Technology/ Canal Construction	Ostracodes	Transition from opportunistic use of water to functional canal operation between 3000 and 2400 years ago.
	Pollen	Grass and cattails part of brush baffle construction.
Canal Operation/Flow Regimes		
A. Distance from source intakes	Pollen	Pine pollen percentages and sediment texture can serve as a general gauge of distance from the canal headwaters.
B. Canal Operation/ Maintenance	Mollusks and ostracodes	Reveal episodes of desiccation and standing water, suggesting closed headgates, periods of flowing or stagnant waters, and patterns of canal salinization and dilution.
	Pollen	Sediment and pollen data can indicate long-term flows. Pollen abundance and sediment texture correspond to canal flow regimes. Cattail pollen can signify slow or stagnant water. Canal clean-out sediments along levees contain a diversity of water-borne pollen types, along with pollen from weedy plants growing along canals.
	Pollen and macrofossils	Canal-clogging vegetation was likely burned as routine canal maintenance. Agricultural fields were also burned to prepare for planting.
C. Season(s) of canal operation	Ostracodes and ostracode shell chemistry	Ostracodes occupied canals between late winter and early summer. Another study suggested relative temperatures.
	Pollen	Spring and summer flows have been interpreted from specific pollen spectra.
D. Cultivation/Encouragement of plants along canals	Pollen and macrofossils	Maize, cotton, and squash pollen recovered in canal sediments. Wild plants (e.g. Cheno-ams, agave, cholla) likely encouraged along canals or along the edges of nearby agricultural fields.
Canal capacity/rank within an irrigation system	Ostracodes	Different ostracodes possibly represent main vs. distribution vs. lateral canals. More work needed.
	Pollen	Main canals produce the most general pollen spectra, with pollen specificity increasing with decreasing canal rank. Crop pollen highest from smaller canals.
Irrigation technology through time	Ostracodes, mollusks and pollen	Too few studies to determine any patterns related to pre-Classic vs. Classic time periods. Also, hard to date canals.
Water storage: reservoirs, clay basins	Macrofossils	Revealed reservoir held water for long periods.
	Ostracodes	Revealed reservoir held water for a long time. Water kept permanently available along trade routes, possibly.
	Pollen	Some features were more likely pottery clay-settling basins, rather than water storage reservoirs.
Differentiating irrigation features from cultural features	Ostracodes and mollusks	Their very presence suggests water presence in the past.
	Pollen	Riparian and high pine pollen values can help differentiate water control features, as does sediment texture.
Climate change	Ostracode shell chemistry	Used to suggest periods of climatic change, including flood events and increasing temperature between the A.D. 1200s and 1450s.

If floodplain stability was a key ingredient in the development of canal irrigation in southern Arizona during the Early Agricultural period, then subsequent floodplain instability due to changing flood regime likely impacted prehistoric canals and irrigation communities. Historic records demonstrate nicely that floods and droughts had a deleterious impact on earthen canal systems (Ackerly 1991; Huckleberry 1999b; Nials and Gregory 1989). The big question is when and to what degree did floods and droughts stressed indigenous agriculturalists (see Ackerly and Henderson 1989; Ackerly, Howard, and McGuire 1987; Nials et al. 1989; Masse 1991a; Howard 1994; Huckleberry 1995b, 1999a; Waters and Ravesloot 2001). Drought information is contained in dendrohydrological reconstructions of prehistoric runoff for the Salt and Verde Rivers (Graybill 1989; Van West and Altschul 1997) and the Gila River (Graybill 1999). These reconstructions have also been used to infer past floods, but important flood events can be missed in the tree-ring record (Ackerly 1989). For example, as Ackerly (1989:73) states, "there is unequivocal evidence suggesting that the magnitude of peak flood events cannot be predicted during below-average discharge years."

A more direct record for paleofloods is alluvial stratigraphy. Most paleoflood information is from slackwater sites located largely in the upper watershed, where streamflow is confined and deposits can be used to reconstruct flood frequency and magnitude (Ely et al. 1993; House et al. 2002). Such locations tend to be located upstream from areas of canal irrigation, and it is uncertain to what degree floods in lower-order tributaries of the upper watershed affected the downstream alluvial valleys. Alluvial stratigraphy from the lower valleys is more difficult to access (fewer natural exposures), but preliminary studies (Huckleberry 1999c; Waters and Ravesloot 2000, 2001) suggest that flood frequency and magnitude also varied in time in locations where prehistoric agriculturalists dug their canals and watered their crops. Indeed, temporal correlations between changes in flood regime based on alluvial stratigraphy and changes in settlement patterns have been used to argue for flood-induced damage to canal systems and abandonment of irrigation communities (Huckleberry 1995b; Waters and Ravesloot 2001). These studies seem to suggest that floods and channel dynamics contributed to cultural changes associated with the Hohokam Sedentary-to-Classic-period transition (A.D. 1050–1150) but were not solely responsible for the Hohokam collapse during the fifteenth century. The question remains as to whether a combination of floods and droughts played a significant role in the collapse of agricultural settlements during the 1400s (Graybill 1999; Nials, Gregory, and Graybill 1989).

When destructive floods do occur, they damage canal intakes and deposit alluvium within the canal alignment. Therefore, canals may contain stratigraphic evidence of past floods and represent a source of paleoflood information. In some cases, entire canal channels are buried in the subsurface by overbank flood deposits or contain coarse-textured alluvium suggestive of destructive flooding. However, a survey of canal stratigraphy from Hohokam canals in the lower Salt River Valley suggests that most of the canals lack clear evidence for flooding (Huckleberry 1999a). This may be due to an inability to recognize flood deposits in canal channel segments located far from their river intakes or to incomplete preservation of the upper channel. Future study of canal segments should involve stratigraphic and sedimentological analyses designed to identify evidence of past floods within both the extant channel and adjacent deposits.

In addition to the effects of environmental change on the operation of canal systems, canals themselves are vectors of environmental change. For example, historic canal irrigation in the Santa Cruz River at Tucson contributed to gullying and arroyo formation in the 1890s (Betancourt 1990; Waters 1988). Prehistoric canal construction may have likewise affected other streams in Arizona, although identifying such anthropogenic effects is problematic, given the multitude of natural hydroclimatological variables responsible for floodplain changes. A more recognizable impact of canal irrigation on the environment is chemical and morphological modification of soils. Prolonged canal irrigation in the Old World resulted in degraded and salinized soils, contributing to the collapse of ancient agricultural societies (Hillel 1991; Redman 1999). Canal irrigation in Arizona occurred at smaller spatial and temporal scales, and although there is evidence for changes in canal-water salinity through time (Palacios-Fest 1994), soil salinity appears to have been ephemeral and manageable (Ackerly 1988; Huckleberry 1992). The most common soil impact from irrigation appears to have been deposition of fines and modification of texture and structure. Linear patterns of distinct soils in the Phoenix Basin have been linked to Hohokam canals (Dart 1986), and textural gradients in modern surface horizons have been spatially related to relict canals (Huckleberry 1992). Hence, documentation of irrigation-affected soils adjacent to relict canals can provide insight into anthropogenic environmental change.

Finally, prehistoric canals are windows into Arizona's past environment, when rivers and wetlands were much more extensive than today. Most of Arizona's floodplains have been radically altered by over one hundred years of Euroamerican water diversions, groundwater pumping, and agricultural/urban development (Dobyns 1981; Rea 1983). The quality and appearance of those original floodplains have largely been forgotten. Canals were tied to these riparian oases and contain paleoecological remains that record environmental attributes of these past biotically rich communities. Pollen, freshwater shell, and ostracodes from canal deposits may prove useful for studying these past wetlands and how they were utilized and influenced by indigenous farmers prior to Euroamerican settlement.

Formation Processes

In the analysis of relict irrigation features, an investigator must consider the multiple cultural and natural formation processes that can modify these features (Figure 5.18). Relict canals, whether buried or at the surface, are normally quite different from the canals as originally designed and the way they appeared during their final days of operation. Most canals are abandoned and then slowly effaced or buried by natural surficial processes, primarily surface runoff. Canals located outside of floodplains on relatively stable geomorphic surfaces may persist several centuries after abandonment. In the lower Salt Valley, many Classic period Hohokam canals were still visible at the surface during Euroamerican settlement in the late nineteenth century, but were soon renovated for irrigation or simply plowed over (Halseth 1932). If one wants to know how these systems looked and operated prior to abandonment, one needs to be cognizant of the many possible post-abandonment transformations that can occur and use extant stratigraphy to work backwards and reconstruct the original design (see Schiffer 1987).

Canal-formation studies usually involve identifying the origin of sediments within the canal channel and considering the canal's hydraulic properties. Abandoned canals mostly contain alluvial sediments (although eolian and colluvial sediments and human-emplaced fill are also possible). Analysis of channel fill and adjacent soil granulometry combined with a consideration of bedform features allows for the interpretation of the origin of canal sediments and their environment of deposition. One of the most important applications of this information is determining which sediments represent active use of the canal and which represent post-abandonment sedimentation (Huckleberry 1991). This may be problematic where stratigraphy has been bioturbated or where floodwaters entered an abandoned alignment. However, knowing which deposits formed during or after the operating life of the canal is critical for interpreting chronological, paleoecological, and hydraulic data.

Alterations to the original design of a canal may have occurred as a result of natural hydraulic adjustment. Earthen canals have mobile beds in which sediment is in flux, and the depth and width of the channel will self-adjust in an effort to best accommodate the transport of water and sediment (Farrington and Park 1978). Where the adjacent soils are cohesive, these adjustments occur within the human-excavated channel. However, canals in riverine floodplains commonly transect loose, sandy alluvium that is prone to scour. Under such conditions, canals have greater liberty to self-adjust their channel geometry, resulting in numerous inset channels with laterally extensive horizontal boundaries

(Huckleberry 1987). Channel shape transformations also may be more directly caused by humans due to maintenance and remodeling activities. For example, Hohokam canals generally experienced siltation and required constant cleaning and maintenance (Haury 1976; Huckleberry 1991; Turney 1929). Also, it is common for abandoned canals to be reutilized by excavating a new channel either partly within or parallel to the earlier channel (Howard and Huckleberry 1991; Masse 1981). Events such as these will be demarcated by unconformities in canal stratigraphy. The stratigraphic and sedimentological properties of multichanneled alignments should be documented to help determine the relative sequence of channel change and whether the alterations were more likely natural or cultural. Paleohydraulic analysis can help in this endeavor by reconstructing water velocity and assessing canal channel stability.

Cultural Considerations

Canal irrigation systems represent one of many land-use strategies that are components of larger subsistence-settlement systems, and consideration must be given to the context of specific features within the cultural realm. Beyond the task of property-type identification, the most basic level of investigation, researchers must determine the spatial position of an irrigation feature within the overall canal system. That is, for instance, is the feature situated in an agricultural field or a village, or is it a segment of a main canal? Some property types (e.g., aqueducts, field features, headwater features) are not well documented, thus increasing the value of their discovery and additional study. Also, it is important to assess the temporal placement, as well as the longevity (i.e., use-life), of irrigation features in the development of a canal system. Research in the lower Salt Valley (e.g., Ackerly and Henderson 1989; Ackerly, Howard, and McGuire 1987; Hackbarth, Henderson, and Craig 1995; Howard and Huckleberry 1991), for instance, has shown that the large-scale Hohokam canal systems were not progressively elaborated through time. That is, canals were not continuously used, but rather alignments often were abandoned and rebuilt sequentially throughout the system's history. Thus, the magnitude of multi-channel systems can be overestimated by assuming that all canals were long-lived and used at the same time. In addition, the relative importance of canal irrigation as a subsistence source should be assessed as well. For example, irrigation clearly represented the major subsistence effort for the Phoenix Basin Hohokam, whereas the Hohokam and other groups in the Tucson and Tonto basins appear to have relied more on other agricultural techniques.

In turn, the characteristics of irrigation features and canal systems have important implications for assessments of agricultural productivity, population size, labor requirements, and social organization. For example, canal discharge can be used to estimate irrigable acreage (e.g., Ackerly and Henderson 1989; Ackerly, Howard, and McGuire 1987; Crown 1987a; Haury 1976; Howard 1994; Masse 1981). These estimates can be used in conjunction with streamflow and soil data and estimates of irrigable land and crop yield to model agricultural productivity, which, in tandem with assumptions about food consumption, may further be used to model population size (e.g., Van West and Altschul 1997; Waters 1998). Labor requirements and water-management strategies also have been assessed using data from canal features (e.g., Ackerly 1982; Ackerly, Howard, and McGuire, 1987; Haury 1976; Neitzel 1991:*194–198*; Nicholas and Neitzel 1984; Woodbury 1961a).

Finally, the role of irrigation has figured prominently in debates about social organization and the development of sociopolitical complexity (e.g., Adams 1966; Downing and Gibson 1974; Mabry 1996; Wittfogel 1957). For instance, the Hohokam traditionally were cited as an example of a society having a simple sociopolitical organization that constructed and operated an extremely large scale irrigation network (e.g., Woodbury 1961a). However, the large-scale irrigation networks of the Hohokam have played a central role in debates about whether the development of the Hohokam conformed to the hydraulic hypothesis (e.g., Howard 1987, 1990; Nicholas and Neitzel 1984; Wilcox

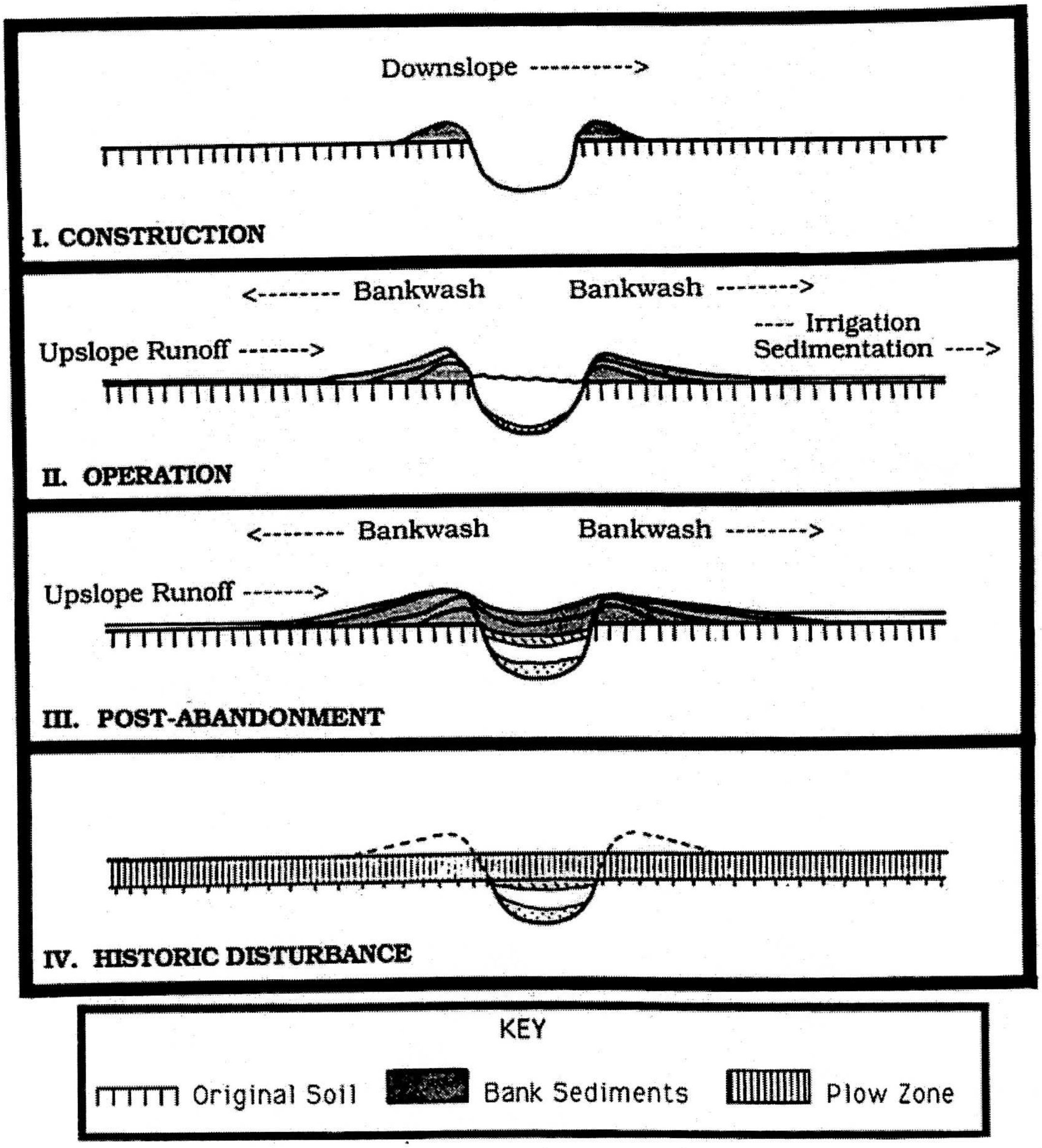


Figure 5.18. Formation and depositional processes of a prehistoric canal (from Huckleberry 1992:239; courtesy of *Kiva* and the Arizona Archaeological and Historical Society).

1979). While an interest in these issues lapsed through the late 1950s and into the 1980s, the research issues concerning the relationships between irrigation and sociopolitical complexity in the Phoenix Basin (e.g., Abbott 2000; Breternitz 1991; Howard 1987, 1990) and the other river valleys (e.g., Craig 1995) are again being addressed by archaeologists working in Arizona.

SUMMARY

Canals and irrigation features are an important legacy of Arizona's past. They are features that connect the human and natural components of the landscape. The prehistoric inhabitants of Arizona adopted canal irrigation technology in diverse settings across a wide span of time beginning in the Early Agricultural period. In some areas, such as the Phoenix Basin, large-scale irrigation agriculture (Figure 5.19) endured for over a millenium, a testament to the productivity and sustainability of Hohokam subsistence technology. In other areas, canals were used relatively briefly for farming or simply were used to divert water into reservoirs. In all areas, irrigation agriculturalists had to contend with and adapt to constantly changing natural and social environments.

This chapter has presented an overview of the cultural, spatial, and temporal settings of canals and irrigation features in Arizona, canal irrigation property types, and methods of investigating canal systems and irrigation features as the basis of a historic context for prehistoric canal irrigation in Arizona. Procedures for evaluating the integrity, significance, and National Register eligibility of canals and irrigation features are presented in Chapter 6 and data gaps and future research directions are outlined in Chapter 7.

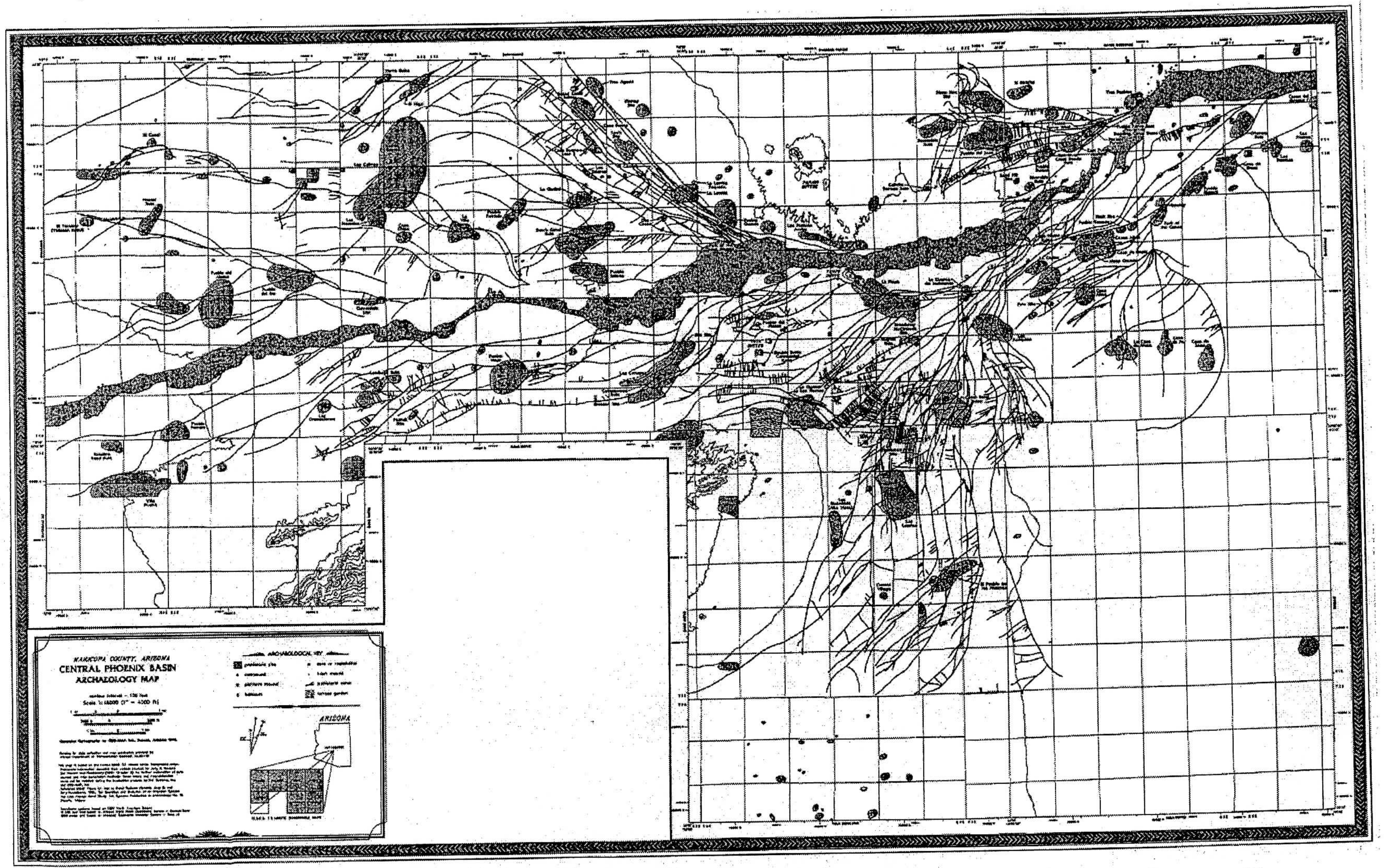


Figure 5.19. This map shows the known distribution (as of 1991) of prehistoric Hohokam canals within the Phoenix metropolitan area. The map was compiled by Jerry Howard (1991) from earlier historic and more recent maps by Herbert Patrick, Omar Turney, and Frank Midvale, and more recent archaeological investigations. The map was produced by Soil Systems, Inc. under contract to the Arizona Department of Transportation. Figure courtesy of Jerry Howard.

APPENDIX A:
CANAL PALEOHYDRAULICS AND MODELING

Gary Huckleberry

Paleohydraulic analyses are typically performed on relict canals in order to define their engineering efficiency and capacity to deliver water (Ortloff, Feldman, and Mosely 1985). That many modern canals follow the alignments of their prehistoric predecessors is a testament to the hydraulic efficiency of these systems. Paleohydraulic analysis provides more detailed evaluation of engineering efficiency by considering changes in water velocity and discharge in response to changes in channel shape and gradient at different points within a given system (e.g., Ackerly, Howard, and McGuire 1987; Busch, Raab, and Busch 1976; Howard 1994). Such information also allows for an assessment of the amount of water these canals could carry. Prehistoric and historic canals in Arizona were used mainly to grow crops, and thus defining these systems' irrigation capacities provides insight into the carrying capacity of specific irrigation communities. Although irrigation communities were skilled in combining floodwater, canal, and dry farming in their agricultural repertoire, in most riverine settings they were heavily dependent on canals for the security of they food supply. Consequently, the hydraulic properties of relict canals in Arizona have been studied and related to potential irrigable area (e.g., Crown 1987a; Haury 1976; Howard 1994; Mabry and Holmlund 1998; Katzer 1989; Masse 1981; Nials, Gregory, and Graybill 1989).

Most relict canal systems have relatively low gradients (e.g., < 1 m/1000 m) with relatively uniform channels, such that flow tends to be subcritical, i.e., Froude numbers less than 1. Consequently, simple open channel equations such as the Manning formula can be employed to provide a reasonable estimate of water velocity (see French 1985). Discharge (the amount of water passing through a given channel cross section in a given unit of time) is then determined by the continuity equation, whereby velocity is multiplied by the cross-sectional area of the channel. Key parameters for using the Manning equations are hydraulic radius, gradient, and roughness. Width and depth are determined from cross-section profiles and used to estimate hydraulic radius. Traditionally, hydraulic radius for irregularly shaped canal channels was estimated using simple equations for approximate channel shapes (e.g., parabolic, trapezoidal, rectangular). However, today computer-assisted drafting and image-analysis software can be used to calculate hydraulic radius more accurately through precise measurement of cross-sectional area and wetted perimeter (Mabry and Holmlund 1998). Gradient is typically estimated either by measuring the elevation of the base of the channel over distances greater than 100 m or by using regional slope (Howard 1991). Hydraulic roughness, or "Manning's n," is estimated based on texture and uniformity of channel boundaries (French 1985); most researchers have used coefficient of roughness values between 0.25 and 0.40 in water velocity reconstructions for canals.

The accuracy of velocity and discharge calculations based on the extant channel dimensions of relict canals is uncertain, given that most relict canals are missing their upper dimensions, and only the lower parts of the channel are typically used to determine width and depth. Many of the above parameters can only be approximated in the field. In some situations, a greater depth can be estimated for canals that contain alluvial particle sizes requiring velocities greater than those retrodicted from extant dimensions (Huckleberry 1991), but this seems to work more for smaller distribution and field lateral channels than main canal alignments. Another problem concerns "channels within channels" due to scour and/or dredging, such that it may be difficult to determine which channel should be used for measuring width and depth (Nials and Gregory 1989). Also, extant width may be exaggerated due to scour and lateral expansion, resulting in a non-representative cross-sectional area. Even in cases where the entire channel is preserved at the surface and the full dimensions can be measured, the issue still remains as to what depths were typically used during operation of the canal. Some freeboard is usually employed in canal irrigation so as to avoid bank erosion (Zimmerman 1966), but there is no indication of an "average" water surface elevation. Accurate reconstruction of velocity and discharge is also limited by the estimate of gradient used in the Manning equation. Technically, the gradient should be based on the slope of the water surface in an open channel. Changes in elevation of the channel base within a project area or the use of a regional gradient may not reflect true hydraulic gradient.

Given these limitations, how much credence can we place in paleohydraulic reconstructions? Most earthen canals can support only a limited range of water velocities. Velocities less than 0.3 m/s tend to result in excessive siltation, and velocities greater than 1.0 m/s tend to result in channel erosion, depending on boundary conditions (Huckleberry 1991). Paleohydraulic reconstructions of water velocity tend to fall within this range and are likely reasonable estimates of flow speed and energy in the canal. Canal discharge estimates are less certain. Most reconstructions of canal discharge overestimate actual discharge, depending on the degree of channel preservation. For example, Ackerly (1991) performed paleohydraulic calculations on historic canals in the Phoenix Basin using the Manning and continuity equations and determined that reconstructed discharges tend to be more than twice the gauged discharge. Exaggeration of true discharge, however, may be moderated by the fact that most relict canal flow reconstructions are based on partial channel dimensions that yield conservative estimates of flow depth.

Canal discharge estimates are subsequently applied to estimates of irrigable area (e.g., Haury 1976; Howard 1994; Mabry and Holmlund 1998; Nials, Gregory, and Graybill 1989). These estimates are based on assumptions of irrigation requirement for various crops, seepage and evaporation losses within the canal system, and efficiency of the water-delivery system to field areas. Historic analogs provide some reference for estimating these parameters, but as in the case of discharge reconstructions, it is difficult to assess the accuracy of the resulting estimates of irrigable area. Results can vary considerably depending on which parameters are selected in the calculations. Nonetheless, paleohydraulic-based estimates of canal irrigation capacity and food production are at least empirically based and are likely more accurate than such estimates based on the amount of arable land downslope from main canal alignments. Moreover, paleohydraulic studies based on excavation of relict canal channels provide a means for testing models of canal expansion that may not be feasible, given hydraulic constraints of the system (e.g., Howard 1994).

In the future, three-dimensional mathematical modeling of runoff, canal discharge, water application, and crop production may provide accurate and precise estimates of prehistoric irrigation agriculture in Arizona. In terms of discharge reconstruction, some of the U.S. Army Corps of Engineers HEC flow model series could be used on individual canal alignments. However, the accuracy of such an endeavor would be limited by the ability to define hydraulic parameters such as flow depth, gradient, hydraulic roughness, seepage, and other traits. Given that most of the hydraulic parameters used in the HEC model would have to be estimated based on cross sections of incomplete canal channels, the results are likely to excel in precision but lack in accuracy. Probably more fruitful in the near future will be the application of simulation models (e.g., Lansing 1996) that are less mechanistic and instead focus more on social and ecological factors in traditional canal irrigation and food production.

APPENDIX B:
PROSPECTS FOR ARCHAEOMAGNETIC DATING OF CANAL SEDIMENTS

Jeffrey L. Eighmy

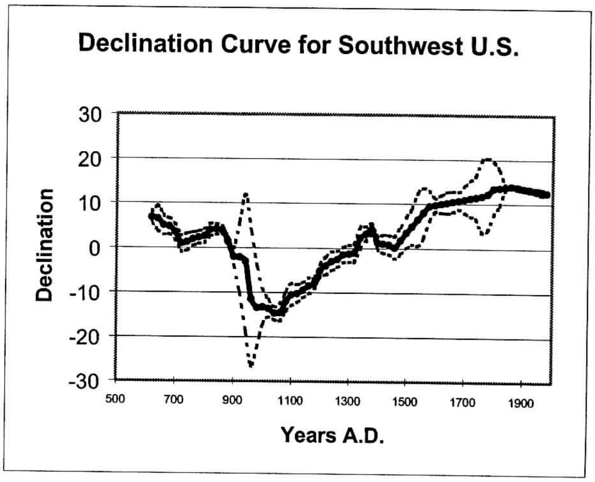
As archaeomagnetic sampling of burned material for dating purposes has become more common and standardized, archaeomagnetists are beginning to explore other materials that might be useful in magnetic dating. Of these, the most promising is sedimentary material. Although there are a number of problems associated with implementing this type of dating, sedimentary records from lakes cores have the potential for producing long and continuous records of secular change in the geomagnetic field. Another important application of the technique in the U.S. Southwest is within the dating of canal sediments (Batt and Noel 1991; Eighmy and Howard 1991). As canals slowly drain and dry out, the magnetic grains align with the earth's magnetic field (McNish and Johnson 1938). Small ferromagnetic particles settling through the muddy water and basal muck rotate mechanically to an orientation parallel with the ambient magnetic field. In the context of natural sediments, this type of magnetism, called detrital remanent magnetism or DRM, will acquire a direction and intensity related to the earth's magnetic field.

This discovery that sediments can and do preserve a magnetization reflecting the earth's field stimulated great interest in measuring changes in the remanent magnetism of glacial varves, lake sediments, and deep-sea sediments as records of secular change in the direction and intensity of the earth magnetic field. Long sequences of secular change were recovered and independently dated (usually by the radiocarbon method) to produce absolute chronologies of change in the direction and intensity of the earth's magnetic field (Creer et al. 1972; Mackereth 1971; Verosub 1988). Most experimental results indicate that the DRM relates to the period of initial sedimentation and consolidation, and rarely to post-deposition events (Katair, Tause, and King 2000).

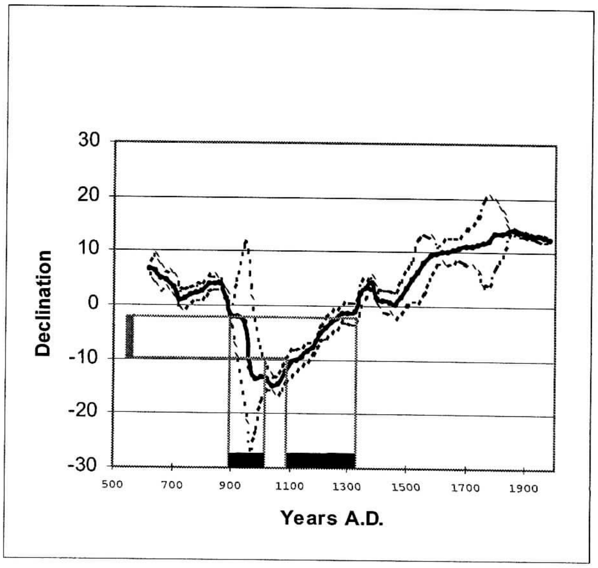
In most cases, however, the inclination recorded by natural sediments appears to be too shallow. One of the important theoretical questions in dating sediment samples concerns the problem of shallow inclination, and the conditions under which this occurs. Inclination error has been recorded in sediments in lab experiments, in lake sediments, and in some historic and prehistoric canals (e.g., Barton, McElhinny, and Edwards 1980; Barton and McFadden 1996; Eighmy and Howard 1991; Verosub 1977). Shallow inclinations appear to result from the fact that magnetized grains tend to settle against the substrate surface as the sediment dries and consolidates; as a result, the inclination tends to be distorted toward the horizontal plane rather than dipping with the earth's field. In cases in which the inclination may be inaccurate, the sediments generally record declination values accurately. Eighmy and Howard (1991:92) show, for example, that for two Phoenix-area canals abandoned in the 1930s, the declinations values bracket the 1930 declination value of 14.5°. The inclination values were consistently and significantly lower than the observed inclination of 60.0°.

By the mid 1970s, it became increasingly evident that the secular variation records from sediments might provide a means of dating archaeological sediments (Clark 1979; Eighmy and Howard 1991; Nichols 1975; Tarling 1983). Theoretically, sediment can be dated in much the same way as burned features that have a thermal remanent magnetization (TRM). The direction and intensity of sediment can be compared to a master record of secular change in the direction and/or intensity of the magnetic field. Periods when the sample direction and/or intensity are similar become the possible dating range. As in TRM-based dating, attention in DRM-dating in archaeology has focused almost exclusively on change in the paleodirection as a means of dating sediment samples. Attention is focused further on the declination component of directional change due to the fact, mentioned above, that inclination values are often too shallow. The precisions of age estimates produced by this method for canal sediments in the U.S. Southwest are usually no greater than ± 75 years.

The figure at right illustrates the declination curve for the U.S. Southwest. Dashed lines parallel to the main line represent 95% confidence intervals.



As an example of DRM dating using declination values, consider a sediment sample collected from the U.S. Southwest that records a declination of 6.0° ±4.0° (see figure at right). Based on the master curve of declination change in the U.S. Southwest, declination values there fell between 2.0° and 10.0° during the A.D. 900 to 960 and the A.D. 1090 to 1310 periods. These periods are most likely the periods when the sediment consolidated.



CHAPTER 6

NATIONAL REGISTER OF HISTORIC PLACES EVALUATION OF PREHISTORIC WATER UTILIZATION AND TECHNOLOGY PROPERTIES

Michael S. Foster

The goal of this chapter is to summarize the NRHP evaluation process, and the evaluation and eligibility requirements of different property types associated with prehistoric water utilization and technology in Arizona. The National Historic Preservation Act (NHPA) of 1966 established the framework for historic preservation in the United States. Its enactment resulted in the NRHP, the Advisory Council on Historic Preservation, state historic preservation offices and programs (including tribal historic preservation programs), and the Section 106 process. As a result, federal agencies are required to take into account the effects of their actions on historic properties and archaeological sites. This chapter summarizes the NRHP eligibility criteria and discusses the role of a property's integrity in determining eligibility, as well as the role of historic context. The guidelines for evaluating NRHP eligibility are presented in a number of bulletins published by the National Park Service (NPS). This chapter follows the NPS National Register Bulletins entitled *How to Apply the National Register Criteria* for Evaluation (NPS 1997) and *Guidelines for Evaluating and Registering Archaeological Properties* (Little et al. 2000). These guidelines are available at the NPS web site on the World Wide Web at http://www.cr.nps.gov/nr/publications/bulletins/nr15_toc.htm. Information is also available at the Arizona State Historic Preservation Office web site at http://www.pr.state.az.us/partnerships/shpo/shpo.html.

To be eligible for the NRHP, a property must represent a significant part of the history, architecture, archaeology, engineering, or culture of an area. A property also must possess qualities that make it a worthy example of properties associated with that aspect of the past. To be listed in the NRHP, properties must also have integrity and must be derived from an identifiable historic context (NPS 1986:6). The following abridged discussion of assessing eligibility is taken from Chapter IV of Little and others (2000). Little and her co-authors have done an excellent job of explaining this complicated process. The reader is strongly advised to consult this NPS Bulletin for detailed discussion and numerous examples of how the process should work, how it should be interpreted, and what it is meant to do. Considering the array of property types discussed in this document, the nature of these features, the variability of their integrity, their role in overall settlement and subsistence systems, and the variability of their research potential, it is important to have as clear as possible of an understanding the application of NRHP eligibility criteria to these cultural resources. In the following discussion, we quote extensively from Little and other (2000).

EVALUATING ARCHAEOLOGICAL PROPERTIES UNDER THE CRITERIA

> The use of Criteria A, B, and C for archeological sites is appropriate in limited circumstances and has never been supported as a universal application of the criteria. However, it is important to consider the applicability of criteria other than D when evaluating archeological properties. The preparer should consider as well whether, in addition to research significance, a site or district has traditional, social or religious significance to a particular group or community. It is important to note that under Criteria A, B, and C the archeological property must have demonstrated its ability

> to convey its significance, as opposed to sites eligible under Criterion D, where only the potential to yield information is required.
>
> ## Criterion A: Event(s) and Broad Patterns of Events
>
> Mere association with historic events or trends is not enough, in and of itself, to qualify under Criterion A–the property's specific association must be considered important as well. Often, a comparative framework is necessary to determine if a site is considered an important example of an event or pattern of events.
>
> Archeological sites that are recognized "type" sites for specific archeological complexes or time periods are often eligible under Criterion A. Because they define archeological complexes or cultures or time periods, type sites are directly associated with the events and broad patterns of history. In addition, archeological sites that define the chronology of a region are directly associated with events that have made significant contributions to the broad patterns of our history.
>
> Properties that have yielded important information in the past and that no longer retain additional research potential, such as completely excavated archeological sites, must be assessed essentially as historic sites under Criterion A. Such sites must be significant for associative values related to: 1) the importance of the data gained; or 2) the impact of the property's role in the history of the development of anthropology/archeology or other relevant disciplines. Like other historic properties, the site must retain the ability to convey its association as the former repository of important information, the location of historic events, or the representation of important trends. For instance, a completely excavated pre-contact quarry site known to have been the only quarry site utilized by Native Americans in a northeastern state has revealed important information concerning the seasonal rounds of Native groups, and the procurement and reduction of local lithic materials. Information about how mining materials from this quarry functioned within the overall cultural system of the area and affected settlement and subsistence practices and the intact physical environment of the site convey its importance as the best example of pre-contact industry and commerce in this locale. The quarry is visible, located in a remote area, and maintains integrity of location, setting, feeling, and association. The site would be eligible at the local level of significance under Criterion A, but not D. The site may not be eligible at the state level of significance under Criterion A, as it may not exemplify an important quarry, comparatively, for the region [Little et al. 2000:22].

Some sites could be listed because of their significance in the history of archaeology. Snaketown, for example, is the type-site for the early portion of the Hohokam sequence in the Gila and Salt River valleys. The early excavations (Gladwin et al. 1937) and Haury's (1976) subsequent reinvestigation resulted in the definition of the phase sequence and the identification of an array of features and artifacts. The typological classifications established are still widely used today. The subsequent restudy of the Snaketown data by Wilcox, McGuire, and Sternberg (1981) resulted in the identification of courtyard groups, a dramatic new insight into Hohokam village structure and sociopolitical organization. Snaketown certainly has a long and significant role in the history of archaeology in Arizona.

Hohokam irrigation and irrigation systems might be considered under Criterion A as a series of linked events or a historical trend. The emergence of prehistoric irrigation in the Arizona desert, the evolution of irrigation systems and technology, and the impact of irrigation agriculture on Hohokam social, economic, and political structures is clearly an important historical trend. Such an example is the Pima Irrigation Sites National Historic Landmark, listed in the National Register of Historic Places under Criterion D.

Criterion B: Important Persons

> In order to qualify under Criterion B, the persons associated with the property must be individually significant within a historic context. The known major villages of individual Native Americans who were important during the contact period or later may qualify under Criterion B. As with all Criterion B properties, the individual associated with the property must have made some specific important contribution to history. Examples include sites significantly associated with Chief Joseph and Geronimo[Little et al. 2000:24–25].

It is highly unlikely that any property associated with prehistoric water technology and utilization would be eligible under Criterion B. Again, for a property to be eligible because of its association with an important person, that person must be of significant local, state, or national stature, the property must be illustrative of the person's life, and the property must retain its integrity. Since no prehistoric individuals of local, state, or national significance have been identified by name, or are known to be associated with a specific property in the category, it would be difficult to nominate a property using Criterion B. Nevertheless, it might be possible for a specific property because of association with a traditionally identified person, real or perhaps even mythological, at a local or state level. For example, a Native American community or tribe might associate a water source (e.g., spring, well, tinaja) with an important individual through its oral history.

Criterion C: Design, Construction, and Work of a Master

> To be eligible under Criterion C, a property must meet at least one of the following requirements: the property must embody distinctive characteristics of a type, period, or method of construction, represent the work of a master, possess high artistic value, or represent a significant and distinguishable entity whose components may lack individual distinction.
>
> The above requirements should be viewed within the context of the intent of Criterion C; that is, to distinguish those properties that are significant as representative of the human expression of culture or technology (especially architecture, artistic value, landscape architecture, and engineering) [Little et al. 2000:25–26].

Certainly, many of the built properties discussed in this document have the potential to be nominated for the NRHP under Criterion C. Specifically, the technological and engineering aspects of canals, reservoirs, and other water capturing and transport systems can easily be considered under Criterion C. Again, the Pima Irrigation Sites National Historic Landmark is listed in the National Register under Criterion D, but it could be nominated and listed under Criterion C as well. The Marana non-irrigated agricultural fields and the array of features there are a distinctive example of various Hohokam technologies for capturing and retaining water and certainly embody the distinctive characteristics of a type, period, and method of construction.

Criterion D: Information Potential

> Criterion D requires that a property "has yielded, or may be likely to yield, information important in prehistory or history." Most properties listed under Criterion D are archeological sites and districts, although extant structures and buildings may be significant for their information potential under this criterion. To qualify under Criterion D, a property must meet two basic requirements: The property must have, or have had, information that can contribute to our understanding of human history of any time period. The information must be considered important.

Nominations should outline the type of important information that a property is likely to yield as shaped by the applicable research topics. To do this, the property must have the necessary kinds and configuration of data sets and integrity to address important research questions.

There are five primary steps in a Criterion D evaluation.

2. Identify the historic context(s), that is, the appropriate historical and

4. Taking archeological integrity into consideration, evaluate the data sets in terms of their potential and known ability to answer research

Application of Criterion D requires that the important information which an archeological property may yield must be anticipated at the time of evaluation. Archeological techniques and methods have improved greatly even in the few decades since the passage of the NHPA. The questions that archeologists ask have changed and become, in many cases, more detailed and more sophisticated. The history of archeology is full of examples of important information being gleaned from sites previously thought unimportant. Because important information and methods for acquiring it change through time, it may be necessary to reassess historic contexts and site evaluations periodically.

Changing perceptions of significance are simply a matter of the normal course of all social sciences and humanities as they evolve and develop new areas of study. What constitutes "information important in prehistory or history" changes with archeological and historical theory, method, and technique.

Specific questions may change but there are a number of categories of questions that are used routinely to frame research designs in terms of anthropological observations of societies. Such general topics include but are not limited to: economics of subsistence, technology and trade; land use and settlement; social and political organization; ideology, religion, and cosmology; paleo-environmental reconstruction; and ecological adaptation. In addition, a category of questions that relate to improvement to archeological methodology should be considered. For other general categories see the National Park Service *Thematic Framework* (NPS 1996), available at www.cr.nps.gov/history/ thematic.html.

Through the disciplined study of the archeological record and supporting information, archeologists can provide answers to certain important questions about the past that are unobtainable from other sources. Archeological inquiry generally contributes to our understanding of the past in three ways. It:

- describes, records, and reconstructs past lifeways across time and space;
- tests new hypotheses about past activities;

- and reinforces, alters, or challenges current assumptions about the past [Little et al. 2000: 28–30].

It is likely that properties associated with prehistoric water utilization and technology will be nominated to the NRHP under Criterion D. In other words, such properties will yield or are likely to yield important information regarding past human history.

Aspects or Qualities of Integrity

The National Register criteria stipulate that a property must possess integrity of location, design, setting, materials, workmanship, feeling, and association. The National Register bulletin *How to Apply the National Register Criteria for Evaluation* directs that "integrity is the ability of a property to convey its significance" and "to retain historic integrity a property will always possess several, and usually most, of the aspects." (For further guidance, see *How to Apply the National Register Criteria for Evaluation).*

The evaluation of integrity is sometimes a subjective judgment, but it must always be grounded in an understanding of a property's physical features and how they relate to its significance. The retention of specific aspects of integrity is paramount for a property to convey its significance. Determining which of these aspects are most important to a particular property requires knowing why, where, and when the property is significant.

The importance of each of these aspects of integrity depends upon the nature of the property and the Criterion or Criteria under which it is being nominated. Integrity of location, design, materials, and association are of primary importance, for example, when nominating archeological sites under Criteria A and B. Design, materials, and workmanship are especially important under Criterion C. Location, design, materials, and association are generally the most relevant aspects of integrity under Criterion D. Integrity of setting within the site is important under Criteria A and B. Under Criteria C and D, integrity of setting adds to the overall integrity of an individual site and is especially important when assessing the integrity of a district. Integrity of feeling also adds to the integrity of archeological sites or districts as well as to other types of properties. Integrity of setting and feeling usually increases the "recognizability" of the site or district and enhances one's ability to interpret an archeological site's or district's historical significance.

Assessment of integrity must come after an assessment of significance:

significance + integrity = eligibility.

To assess integrity, first define the essential physical qualities that must be present for the property to represent its significance.

Second, determine if those qualities are visible or discernible enough to convey their significance. Remember to consider the question of "to whom significance might be conveyed." For example, the significance of particular historic buildings may be apparent primarily to architectural historians but not to many individuals in the general public. Similarly, the significance of some properties may be apparent primarily to specialists, including individuals whose expertise is in the traditional cultural knowledge of a tribe. A property does not have to readily convey its significance visually to the general public; however, National Register documentation of the significance of a property should be written such that members of the general public can understand the property's significance and the physical qualities that convey that significance.

Third, determine if the property needs to be compared to other similar properties. This decision is made in light of the historic context(s) in which the property's significance is defined.

ASPECTS, OR QUALITIES, OF INTEGRITY

Aspect/Quality	Definition
Location	The place where the historic property was constructed or the place where the historic event occurred.
Design	The combination of elements that create the form, plan, space, structure, and style of a property.
Setting	The physical environment of a historic property. Setting includes elements such as topographic features, open space, viewshed, landscape, vegetation, and artificial features.
Materials	The physical elements that were combined or deposited during a particular period of time and in a particular pattern or configuration to form a historic property.
Workmanship	The physical evidence of the labor and skill of a particular culture or people during any given period in history.
Feeling	A property's expression of the aesthetic or historic sense of a particular period of time.
Association	The direct link between an important historic event or person and a historic property. Under D it is measured in the strength of association between data and important research questions.

Finally, based on the significance and essential physical qualities, **determine which aspects of integrity are vital to the property being nominated and whether they are present.**

Solely meeting any aspect of integrity is not sufficient to meet eligibility requirements. For instance, just because most archeological sites retain integrity of location does not make them eligible. As the National Register bulletin *How to Apply the National Register Criteria for Evaluation* states:

> To retain historic integrity a property will always possess several and usually most, of the aspects. The retention of specific aspects of integrity is paramount for a property to convey its significance. Determining *which* of these aspects are most important to a particular property requires knowing why, where and when the property is significant.

Archeologists use the word integrity to describe the level of preservation or quality of information contained within a district, site, or excavated assemblage. A property with good archeological integrity has archeological deposits that are relatively intact and complete. The archeological record at a site with such integrity has not been severely impacted by later cultural activities or natural processes. Properties without good archeological integrity may contain elements that are inconsistent with a particular time period or culture. For example, the contents of a thirteenth-century Native American trash pit should not contain artifacts indicative of a nineteenth-century American farmstead. Because of the complexity of the archeological record, however, integrity is a relative measure and its definition depends upon the historic context of the archeological property.

Few archeological properties have wholly undisturbed cultural deposits. Often, the constant occupation or periodic reuse of site locations can create complex stratigraphic situations. Aboveground organization of features and artifacts may be used as evidence that below-ground patterning is intact. Because of the complexity of the archeological record and the myriad of cultural and natural formation processes that may impact a site, the definition of archeological integrity varies from property to property. For properties eligible under Criterion D, integrity requirements relate directly to the types of research questions defined within the archeologist's research design. In general, archeological integrity may be demonstrated by the presence of:

spatial patterning of surface artifacts or features that represent differential uses or activities;

spatial patterning of subsurface artifacts or features; or

lack of serious disturbance to the property's archeological deposits.

In addressing the presence of nineteenth-century farmsteads, archeologist John Wilson, for example, posed three sets of questions that are helpful in determining the potential archeological integrity of a given site or district (Wilson 1990):

Are the archeological features and other deposits temporally diagnostic, spatially discrete, and functionally defined? Can you interpret what activities took place at the property and when they occurred?

How did the historic property become an archeological site? Were the cultural and natural site formation processes catastrophic, deliberate, or gradual? How did these changes impact the property's archeological deposits?

What is the quality of the documentary record associated with the occupation and subsequent uses of the property? Are the archeological deposits assignable to a particular individual's, family's, or group's activities?

Generally, integrity cannot be thought of as a finite quality of a property. Integrity is relative to the specific significance which the property conveys. Although it is possible to correlate the seven aspects of integrity with standard archeological site characteristics, those aspects are often unclear for evaluating the ability of an archeological property to convey significance under Criterion D. The integrity of archeological properties under Criterion D is judged according to important information potential. Archeological sites may contain a great deal of important information and yet have had some disturbance or extensive excavation (and, thereby, destruction). For example, sites that have been plowed may be eligible if it is demonstrated that the disturbance caused by plowing does not destroy the important information that the site holds.

All properties must be able to convey their significance. Under Criterion D, properties do this through the information that they contain. Under Criteria A, B, and C, the National Register places a heavy emphasis on a property looking like it did during its period of significance. One of the tests is to ask if a person from the time or the important person who lived there, would recognize it. If the answer is "yes," then the property probably has integrity of materials and design. If the answer is "no," then the property probably does not. Keep in mind that the reason why the property is significant is a very important factor when determining what it is that the person should recognize. For example, if a plantation was best known for its formal and informal gardens and agricultural activities, then recognizable landscapes may be more important than recognizable buildings.

One of the most common questions asked about archeological sites and integrity is: Can a plowed site be eligible for listing in the National Register? The answer, which relates to integrity of location and design, is: If plowing has displaced artifacts to some extent, but the activity areas or the important information at the site are still discernable, then the site still has integrity of location or design. If not, then the site has no integrity of location or design.

Sites that have lost contributing elements may retain sufficient integrity to convey their significance under Criterion D. For example, at a 25-acre mound site in the southeastern United States, of four mounds described in 1883, there is now one left associated with an extensive artifact scatter. Repeated surface collections were carried out to better understand the internal organization of the settlement. The nomination states that "On the basis of knowledge of similar sites, subsurface features such as cooking facilities, storage pits, and domestic habitations are likely to exist." One of the research domains likely to be addressed at this A.D. 600-1000 property, which was listed in 1995, concerns the study of the technology and social organization of craft production. The researchers expect to find evidence of rudimentary craft specialization in connection with the emergence of social inequality. At this major mound group, such crafts could have been used by the elite who could control access to or the production of craft items in support of their status.

Location

The location of a property often helps explain its importance. Archeological sites and districts almost always have integrity of location. Integrity of location is closely linked to integrity of association, which is discussed below. Integrity of location would not necessarily preclude the eligibility of secondary or redeposited deposits in an archeological property. Integrity depends upon the significance argued for the property [see Little et al. 2000:38–39 for examples of integrity of location].

Design

Elements of design include organization of space, proportion, scale, technology, ornamentation, and materials. It is of paramount importance under Criterion C and is extremely important under Criteria A and B. The word "design" brings to mind architectural plans and images of buildings or structures. Design, however, also applies to the layout of towns, villages, plantations, etc. For an archeological site, integrity of design generally refers to the patterning of structures, buildings, or discrete activity areas relative to one another. Recognizability of a property, or the ability of a property to convey its significance, depends largely upon the degree to which the design of the property is intact. The nature of the property and its historical importance are also a factor.

Under Criterion D, integrity of design for archeological sites most closely approximates intra-site artifact and feature patterning.

Setting

Setting includes elements such as topographic features, open-space, views, landscapes, vegetation, manmade features (e.g., paths, fences), and relationships between buildings and other features.

Archeological sites may be nominated under Criterion D without integrity of setting if they have important information potential. For example, if a site has rich and well-stratified archeological deposits dating from the 1690s to the 1790s but is located under a modern parking lot and between two modern commercial buildings, it will still qualify under Criterion D. In this case, the setting does not detract from the information potential of the site.

If a site's or district's historical setting (or the physical environment as it appeared during its period of significance) is intact, then the ability of the site or district to convey its significance is enhanced. If the setting conveys an archeological site's significance, then the site has integrity of setting under Criteria A and B. In order to convey significance, the setting should:

appear as it did during the site's or district's period of significance; and

be integral to the importance of the site or district.

Materials

According to the National Register bulletin How *to Apply the National Register Criteria for Evaluation,* "the choice and combination of materials reveal the preferences of those who created the property and indicate the availability of particular types of materials and technologies." Integrity of materials is of paramount importance under Criterion C. Under Criteria A and B, integrity of materials should be considered within the framework of the property's significance.

Under Criterion D, integrity of materials is usually described in terms of the presence of intrusive artifacts/features, the completeness of the artifact/feature assemblage, or the quality of artifact or feature preservation.

Workmanship

Workmanship "is the evidence of an artisan's labor and skill in constructing or altering a building, structure, object, or site." It can apply to the property as a whole or to its individual components. Most often, integrity of workmanship is an issue under Criterion C. Under Criteria A and B, integrity of workmanship is important if workmanship is tied to the significance of the property.

Under Criterion D, workmanship usually is addressed indirectly in terms of the quality of the artifacts or architectural features. The skill needed to produce the artifact or construct the architectural feature is also an indication of workmanship. The importance of workmanship is dependent on the nature of the site and its research importance.

Feeling

A property has integrity of feeling if its features in combination with its setting convey a historic sense of the property during its period of significance. Integrity of feeling enhances a property's ability to convey its significance under all of the criteria.

Association

According to the National Register bulletin *How to Apply the National Register Criteria for Evaluation,* "a property retains association if it is the place where the event or activity occurred and is sufficiently intact to convey that relationship to an observer." Integrity of association is very important under Criteria A and B. The association between a property and its stated significance must be direct under these two criteria.

Under Criterion D, integrity of association is measured in terms of the strength of the relationship between the site's data or information and the important research questions. For example, a site with well-stratified archeological deposits containing butchered animal remains has information on subsistence practices over time. There is a strong association between the site's information and questions on subsistence practices. How *to Apply the National Register Criteria for Evaluation,* should be consulted for additional guidance on evaluating integrity [Little et al. 2000:35–42].

NRHP CRITERIA, INTEGRITY, AND PREHISTORIC WATER UTILIZATION AND TECHNOLOGY IN ARIZONA

It is unlikely that either non-irrigated (check dams, contour terraces, etc.) or irrigated (canals) property types would be eligible under Criterion A or B. Under Criterion A, a property must be associated with events that have made a significant contribution to the broad patterns of our history. Although unlikely, it is conceivable that water technology properties could be nominated under Criterion A using themes such as commerce/economics, community planning, ethnic heritage, invention, or government. For example, under ethnic heritage it could be possible to nominate a property that defines the agricultural technology of a prehistoric group that is viewed as ancestral by a local Native American group (e.g., the Hohokam and the O'odham).

The nomination of a water technology property under Criterion B, on the other hand, would be extremely difficult. To be eligible under Criterion B, a property must be associated with the life of a person or persons important in our past. Since it is beyond the limits of archaeological technology to identify specific individuals who lived in prehistoric Arizona, use Criterion B is unlikely.

To be nominated under Criterion C a property must embody the distinctive characteristics of a type, period, or method of construction, or represent the work of a master, or possess high artistic values, or represent a significant and distinguishable entity whose components may lack individual distinction. Criterion C is most often employed to nominate buildings that represent distinctive architectural styles. It is possible that this criterion could be used to nominate prehistoric water technology properties. However, its utility appears somewhat limited. Nevertheless, it is possible (if not likely) that some prehistoric water technology property types (e.g., field systems, canals) possess distinctive characteristics of a type, period, or method of construction that is temporally, spatially, or culturally significant in historical or technological contexts. Clearly some of the water-management systems contain an array features that reflect noteworthy engineering and construction skills. However, to qualify under Criterion C, a property must possess unique characteristics and should possess strong integrity.

For a property to be eligible under Criterion D, it must have yielded or be likely to yield important information on our prehistory or history. Clearly, the NRHP eligibility of prehistoric water technology property types will be most commonly assessed under Criterion D. An array of political, social, ecological, and economic research issues can be addressed by the investigation of prehistoric water technology properties. Additionally, context and integrity will play critical roles in determining the eligibility and research potential of prehistoric water technology properties. If features are eroded, deflated, or otherwise destroyed, their ability to contribute new and important information is likely diminished. Nevertheless, their setting and relationship to other properties or sites and an understanding of their presence within a local or regional setting are research topics worthy of investigation and, as such, may make them NRHP-eligible.

In sum, assessing NRHP eligibility of prehistoric properties associated with water utilization and technology in Arizona is not necessarily an easy task. A variety of issues focusing on research potential, integrity, and context need to be assessed. These properties will not be eligible simply because they exist, and the act of recording their presence may exhaust their research potential. Yet too narrow a focus may result in broader local and regional research issues being ignored.

PREHISTORIC WATER UTILIZATION AND TECHNOLOGY PROPERTIES ELIGIBILITY REQUIREMENTS

How Old is It and Who Made It?

Rock Features

The first step in assessing NRHP eligibility is determining if the property type is prehistoric. Historic and modern period mining claim cairns, ditches, and water diversion features, which may be NRHP-eligible for historical reasons, can easily be misidentified as prehistoric. Huckell (1978) discusses such an example from the Oxbow Hill–Payson Project, where several features that appeared to be check dams were encountered. Upon further consideration, it was concluded that these features were most likely modern water diversion features. Five criteria or reasons were given to support this conclusion: (1) the features were in active drainages; (2) they were very uniform in their construction; (3) much of the rock used in their construction was not available from the immediate area of the feature; (4) very little, if any, prehistoric material (artifacts) was associated with the features; and (5) the features were in good condition and were relatively undisturbed.

More recently, Doolittle, Neely, and Pool (1993) have addressed the same problem and suggest that there are at least 13 diagnostic elements that can be used to distinguish between prehistoric and modern rock alignments and check dams. Eight of these elements deal with aspects of construction, while five relate to current condition or state of preservation. Additionally, each element has several characteristics. Nevertheless, these investigators note that although it is impossible to correlate characteristics and ages with absolute certainty, there are some characteristics that tend to be associated with features built at particular times. In other words, although no single characteristic is, by itself, diagnostic, if all attributes are considered together, there are patterns that emerge that suggest a feature's age.

The 13 elements cited by Doolittle, Neely, and Pool (1993), which mostly apply to multi-course alignments and check dams, are summarized here:

1. Material Source. Obviously, the rocks used in the construction of water control features will be derived from either local or remote sources. It is relatively easy to determine if the materials used in the construction of the feature are local in origin. One simply has to look around the immediate area of the feature and compare the materials in the feature to those in proximity to it. If the nearby materials and those in feature are similar, it is more likely that the feature is prehistoric. If the materials are foreign to the area, it is more likely the feature is modern or historic, significant effort was expended to transport the materials to the site.

2. Number of Courses. Water control features range in size and form from a single row of rock one course high and wide to features that are several courses high and wide. Materials used in single-course features tend to be more uniform in size and are often the size of a basketball or larger, while materials used in features with multiple courses are quite variable in size. Single-course features appear to be primarily prehistoric and are rarely built in modern times. Unfortunately, multiple-course rock features are common in both prehistoric and historic/modern contexts. The Civilian Conservation Corps built many such features in the Southwest during the Depression era.

3. Consistency. Age determinations can be facilitated by assessing the consistency of the size of materials used in multiple-course features. Some features are made from rocks of various sizes, and others are made from rocks that are fairly uniform in size. Features that are constructed from materials of various sizes tend to be prehistoric while those constructed from materials that are uniform in size tend to be modern. If a feature was constructed during prehistoric times from locally available materials, the builders made use of anything that was present in the vicinity of the feature, and thus rock sized would tend to be more variable. Materials brought in tend to be sorted and therefore more uniform in size.

4. Placement. Observing how materials were placed during construction can provide insight into the age of a feature. Multiple-course features are built by either stacking the rocks or dumping of the source material. Visually, stacked rock features look like they were built with care and deliberation, while dumped features look as if they were built as quickly as possible with little deliberation. Features built by dumping are thought to be modern and built with the aid of wheelbarrows or wheeled vehicles. Materials used tend to be nonlocal and more uniform in size. On the other hand, there is little that differentiates prehistoric stacked features from modern stacked features.

5. Plan. Rock alignments can be either straight or arched. Those features that are arched can be arched upstream, that is, with the concave side facing downstream (∩), or arched downstream, with the concave side facing upstream (∪). Features arched downstream tend to be prehistoric; this formation was apparently an attempt to maximize the size of any agricultural plot behind the feature. Features arched upstream tend to be modern. The choice to place the arch upstream may, in part, reflect the recognition of the strength of the arch and be based on the principals of modern dam construction. Unfortunately, it is far more difficult to distinguish between prehistoric and modern features that are straight in plan.

6. Profile. When viewed in profile (from the side), multiple-course rock features are vertical (∟) or are sloped with the top angling upslope or upstream from the base (∠). Clearly, the profile of such features is a function of their height. Features built on gentle grades are usually low in height, vertical in profile, and widely spaced, whereas features built on steep grades are relatively high, have profiles that angle upstream (with the base being wider than the top), and are spaced at much closer intervals. Features with vertical profiles are almost always prehistoric, while sloping features can be either prehistoric or recent. Modern features, often regardless of height, are nearly always sloping. High prehistoric features also tend to look as if they are better built.

7. Elevation. When viewing a feature from the front, that is looking upstream, the top of the feature will either be level or dip (be lower) in the center. Prehistoric features tend to be level, while recent features tend to have dips in the center. It is possible that these dips approximate spillways and were placed there to help control runoff.

8. Setting. The location of rock alignments is of assistance in attempting to determine whether the feature is prehistoric or modern. These features were placed on slopes, on the terraces or floodplains above incised channels, and across incised channels or gullies. Rock alignments placed on slopes are almost exclusively prehistoric. An exception in southern Arizona is reported by Fish and Reichhardt (1983).

It is much more difficult to assess the age of rock alignments built on floodplains and across incised channels. These types of features were built during the prehistoric, historic, and modern periods. Rock alignments built entirely within the confines of gullies are nearly always recent. Such features appear to have been placed in the bottoms of gullies after extensive cutting had already occurred in order to retard any further erosion.

Additionally, if rock alignments occur in proximity to modern features and it seems likely they are associated with those features, then it is likely that they, too, are recent. Also, if a series of features extends down to, and abruptly terminates at a known property boundary such as a section line or some other social, economic, or political boundary, it is likely that the feature is recent.

9. Integrity. Although rock alignments do not deteriorate at a given rate, there is some correlation between age and a feature's state of preservation. The more intact a feature is, the more likely it is to be recent. Deteriorated features show signs of breaching. On side-breached features, one end of the alignment is removed. On center-breached features, one or more courses or the entire central portion of the feature are removed from the feature's central area, with only remnants of the ends of the feature in the banks of the channel. Unfortunately, it is sometimes difficult to determine whether the feature is breached or it was constructed with a dip in the central area. Furthermore, side-breaching in prehistoric and modern features is common and thus not necessarily a strong indicator of age. Center-breached features, on the other hand, are most commonly prehistoric.

10. Eroded Materials. With the deterioration and weathering of rock alignments, materials used in their construction erode downslope due to gravity or water flow or both. This effect is more likely with recent features because water flow is likely to be higher and faster. Prehistoric rock alignments tend to have eroded materials visible on the ground in proximity to the feature. Conversely, recent structures tend to have little construction material below or in proximity to the feature, because it has been washed downstream and out of the local hydrologic system by high-flow and high-velocity discharges.

11. Interstices. Interstices are spaces between the rocks in the feature. In general, the older a feature is, the more sediment and debris there is between the rocks. Thus, prehistoric features have a great deal of sediments in the interstices, historic features have some, and modern ones have little.

12. Trees. Trees are not thought to have been planted on rock alignments, but rock alignments have been built around trees, and trees are sometimes found growing in them. However, the presence of trees and their association with rock features can be an indicator of age. Obviously, features with saplings growing on them can be of any age, while features with large old trees growing through them must be old themselves. Nevertheless, the question is how old. The age of the tree, and thus the minimum age of the feature, might be determined through dendrochronology. It is likely that features containing trees more than 60 years old and located in areas not recently used are prehistoric. However, alignments built around large old trees are probably more recent.

13. Lichens. It suffices to say that lichens, although common on rock alignments, are generally an ambiguous indicator of age. Although these organisms have long lives, there is sufficient variability in growth rates among species to prevent them from being good indicators of age. Furthermore, growth rates are influenced by moisture, temperature, and exposure to sunlight. About the only thing that can be said is that the absence of lichens on a feature probably means that the feature is recent.

Doolittle, Neely, and Pool (1993) conclude their discussion by citing four characteristics that appear to have no value in assessing the age of rock alignments. Three relate to the construction and one has to do with the current condition of the feature. The first characteristic concerns material size. Both prehistoric and historic/modern features are constructed from materials of various sizes. The second characteristic cited is the use of masonry, that is, rocks that have been chipped or otherwise modified to make them fit better in the construction. Neither prehistoric nor modern builders appear to have made much, if any use, of altered stones. The third characteristic is the use of chinking to fill the spaces between rocks in the features. Prehistoric and historic/modern builders used chinking with the same frequency. The fourth and final characteristic discussed is the back area, the area behind and immediately upstream from the feature. The presence or absence of sediment and the amount of sediment present are not necessarily indicators of age. Rates of sediment deposition as well as rates of erosion vary from feature to feature and area to area. Thus, assuming a feature is old simply because a large back area or terrace is present may well be incorrect, as is the assumption that a feature is recent because of the lack of sedimentary deposits behind it. Nevertheless, if actual soil development has occurred in the back area, this can be taken as an indication that the feature is old (Sandor, Gersper, and Hawley 1990). Clearly, Doolittle, Neely, and Pool have demonstrated that assessing the age of rock alignment features in the Southwest is not necessarily easy or straightforward.

Canal Features

It is not uncommon to identify historic or modern canals, as well as prehistoric canals, during subsurface investigations. Assessing the age and origin of a canal may be difficult (see Chapter 5 for a detailed discussion on identifying the origin and age of canals). Obviously, cement-lined canals or canals with cement and metal head gates or canals containing historic or modern trash may easily be excluded from consideration as prehistoric. Canals or ditches that follow grids or parallel historic roads or other features are also likely historic or modern. This, however, does not exclude them from being eligible for the NRHP. Assessment of age and cultural affiliation is also sometimes complicated by the historic reuse of prehistoric canal segments.

1. Location, stratigraphy, and morphology of canal irrigation features and canal systems. If a canal segment is located near a known prehistoric canal alignment, such as those identified on the Howard and Huckleberry (1991), Midvale (1966), Patrick (1903), or Turney (1929) maps, it may be possible to infer the age (prehistoric versus historic/modern) of the canal segment identified. The stratigraphic position of the canal, how deeply it is buried and its relationship to other features (cultural and geomorphic) may also provide the means by which to determine whether the canal is prehistoric. The morphology composition of the canal may also indicate whether it is prehistoric or historic/modern. Does the canal appear to have been used over a long period of time? Prehistoric canals that have been used over a long time may have slowly filled with silt and there may be evidence the channel of the canal grew smaller and smaller. The channel may also have migrated over time; there may be evidence of multiple channels for the same canal adjacent to one another. Is there evidence of prehistoric features such as weir head gates or stones at or near a head gate? Prehistoric farmers made head gates from wood and vegetation to divert water, and they sometimes placed stones above the head gate to help control erosion and the flow of water.

2. Age of canal features and systems. In order to determine the age of a canal segment, it may submit samples for radiocarbon or archaeomagnetic dating. The antiquity of a canal segment may also be assessed by the presence of artifacts such as pottery sherds in the canal, or the association of a canal segment with an archaeological site or other feature of a known age.

Evaluation of Significance

A property may possess significance if it meets one or more of the four NRHP criteria. Moreover, a water-management feature (non-irrigation or canal irrigation) must retain **INTEGRITY** (per the seven categories of integrity) to be eligible for inclusion on the NRHP under any of the four criteria. A property lacks integrity if it cannot convey its significance. In addition to retaining at least one of the seven integrity criteria, a prehistoric water-management feature must be sufficiently intact to convey its significance. A property need not qualify under all seven integrity categories to be NRHP eligible. Nevertheless, the ability of a property to convey its significance cannot be understated.

Summarizing, to be eligible under Criterion D, the most pertinent criterion for evaluating prehistoric water-management features, the feature must have yielded or be likely to yield important information regarding the prehistory of Arizona. Another criterion of potential specific importance is Criterion C, under which a property must "embody the distinctive characteristics of a type, period, or method of construction, or… represent the work of a master, or…possess high artistic values or represent a significant and distinguishable entity whose components may lack individual distinction." Less likely to be invoked because of their general inapplicability are Criteria A and B. Criterion A deals with a property's association with events that have made a significant contribution to the broad pattern of our history, and Criterion B deals with persons significant in our past. This not to say Criteria A and B could not be employed, but in the majority of instances, such specific associations could be or would be very difficult to substantiate. An exception might be, under Criterion B for example, associating a site with someone who has contributed significantly to the study of Arizona prehistory. An illustration that comes to mind is a site like Snaketown, which might be considered NRHP-eligible because of Emil Haury's stature in the annals of Arizona and Southwestern archaeology, or perhaps a canal or canal system might be eligible under Criterion B because of Frank Midvale's pioneering work on Hohokam canal systems.

As noted above, perhaps the first step is determining whether a feature is prehistoric. In terms of assessing integrity, it is highly unlikely that **location** will be an issue. Rarely are prehistoric agricultural features or fields moved intact to other locations. Obviously, if features have been transported or redeposited through either natural (erosion) or mechanical means, they do not possess integrity of location. Such movement also generally results in the destruction of features and, their research potential is therefore destroyed as well. Most water-management sites and fields will likely retain integrity of location. Integrity of **design** is determined by assessing a combination of elements that create the form, plan, space, structure, and style of a property. Water-management features and fields that retain integrity of design will convey the organization, planning, layout, and function of a property. The level of technological and engineering capabilities of a society may also be inferred from design.

It is also unlikely that the assessing integrity of **setting** will cause considerable debate. The setting of a prehistoric archaeological site relates to how the landscape was utilized during the occupation or use of the site. If the site is in an undeveloped location and its features have not been altered significantly or destroyed, it likely retains integrity of setting in that the area conveys how the site was used. However, if the site is surrounded by, or is within, a housing development, it likely lacks integrity of setting. As with location, most water-management features and fields will retain integrity of setting.

Most water-management agricultural features, unless destroyed, will retain integrity of **materials**. That is, they visually convey the materials from which they were constructed. The materials may be local or nonlocal in origin. The materials used to build a feature may convey information regarding the requirements for construction and the socio-economic organization of the people who constructed the features and the site. Similarly, water-management features and fields can convey integrity of **workmanship**. However, this may not be obvious; most non-irrigation agricultural features are made from unmodified stone. Nevertheless, these features can convey the ability of those who constructed them to take unmodified natural materials and turn them into functioning and productive agricultural facilities.

Feeling may be a more difficult aspect of integrity to assess in terms of water management features and fields. To convey integrity of feeling, a property must convey a sense of a particular period of time. It may be difficult to evoke a feeling for the aesthetic sense of a prehistoric time by viewing a water-management feature or field, and, in general, it is unlikely that integrity of feeling will play a contributing role in assessing the NRHP eligibility of water management features and fields. Integrity of **association** deals with a direct link between a property and a historical event or person. It is extremely unlikely that a case for integrity of association could be made when assessing the NRHP eligibility of a prehistoric water-management feature or field.

Excluded Sites

A property or a site may be excluded from the NRHP if: (a) it is owned by a religious institution or used for religious purposes; (b) it has been moved from its original location; (c) it is a birthplace or a grave; (d) it is a cemetery; (e) it is a reconstruction; (f) it was built to commemorate a historic event; or (g) it has achieved significance in the past 50 years. A prehistoric property if by definition more than 50 years old, and it is unlikely that sites and features associated with prehistoric water utilization and technology in Arizona would be excluded from listing on the NRHP because of the other six associations.

SITE TYPES AND SIGNIFICANCE

The NRHP classifies properties as buildings, structures, objects, sites, and districts (NPS 1997:4–5). In Chapters 3, 4, and 5 we classified prehistoric water-management technology properties as features or sites (fields). Again, it is likely that most water-management utilization and technology features and sites will be evaluated for NRHP eligibility under either Criterion C or D. Furthermore, properties are either eligible or they are not eligible. The use of the designation "potentially eligible" for the NRHP under Criterion D is an inappropriate designation and management tool. A property is NRHP-eligible under Criterion D if it has integrity and has yielded or is **likely to yield** important information in history or prehistory. If there is a question regarding the property's likelihood to yield important information, testing can be undertaken to assess the information potential of the property (eligibility testing). If the results of the testing indicate that there is no information, little information, or no new and important information to be gained from further investigation of the property, the property can then be determined NRHP ineligible. To say the least, assessing the NRHP eligibility of prehistoric water-utilization and technology properties is often a challenging process. Features and sites are not automatically NRHP-eligible simply because they are there and have been recorded.

Integrity and the likelihood of providing new information are two major issues in evaluating water use and management features or properties. Integrity of feeling and association are not of primary importance in the research potential of these features. However, virtually all such features will retain integrity of location, or they would not have been identified as archaeological features or sites. They may also retain integrity of design, setting, materials, and workmanship. Additionally, features must possess integrity; they must be intact and not have suffered any subsequent natural or cultural degradation. Eroded or vandalized features or sites are less likely to produce important new information. This is particularly critical, since the investigation of prehistoric water-management features does not often produce abundant new information in the first place. Furthermore, if only a few elements of a once-extensive system remain, their information potential is diminished (Doyel 1993a). The study of complete or more complete systems (e.g., fields, a series of check dams), is far more likely to yield useful information about the system's place within the cultural landscape and how it functioned.

The dating of features or sites is also of crucial importance. If a property can be dated, its potential for providing new and important information is greatly enhanced. If a feature or property cannot be dated, its interpretive value in the historical development of its technology and the associated cultural system is diminished.

Some property types are sufficiently rare that, if they retain any integrity whatsoever, they should be considered for NRHP eligibility under Criterion D. Such property types are those that are seldom documented and include, for example, wells or reservoirs. Any additional understanding of their temporal, cultural, and spatial distribution contributes to a better understanding of prehistory.

On the other hand, a number of water-management feature types have been extensively documented, and we already have a very good understanding of their function and spatial and temporal distribution. Rock piles, for example, are ubiquitous throughout central and southern Arizona, and we have a fairly thorough knowledge of their form, their function, and what was grown on them. Furthermore, sampling of these features frequently is uninformative. Rock pile features and sites do retain integrity of location, but the research potential of these features is debated. Will further investigation of rock piles provide new and important information on, for example, Hohokam subsistence and agricultural techniques? Or will additional information be redundant? If sites are not likely to provide information beyond what was originally recorded, they are not usually considered eligible for listing in the NRHP. The same issues can be applied to other feature types such as check dams, contour terraces, and bordered gardens. These features have been extensively documented in Arizona, and our understanding of their function and role in prehistoric subsistence activities has not changed dramatically in several decades or more. Simply locating and documenting many of these sites may exhaust their research potential.

In many of the cultural resource management reports reviewed for this report, water-management features and systems (sites) are documented simply as individual sites. They are described, passing reference is made to pertinent local and regional comparative literature, and they are recommended to be NRHP-eligible or potentially eligible simply because they are related to prehistoric water management. All too frequently, there is little elaboration regarding why the property is being recommended eligible other than that it may contribute information on prehistoric subsistence or prehistoric socioeconomic organization. There are five steps in determining eligibility under Criterion D (the criterion most commonly cited): (1) identify the property's data set(s) or categories of archeological, historical, or ecological information; (2) identify the historic context(s), that is, the appropriate historical and archeological framework in which to evaluate the property; (3) Identify the important research question(s) that the property's data sets can be expected to address; (4) taking archeological integrity into consideration, evaluate the data sets in terms of their potential and known ability to answer research questions; and (5) identify the important information that an archeological study of the property has yielded or is likely to yield. All five of these elements, as well as integrity, must be taken into account and addressed when recommending a property as NRHP-eligible. Additionally, the SHPO compliance specialists must critically review site descriptions and NRHP assessments. A positive NRHP recommendation should be required to be as explanatory as a negative recommendation.

Evaluating archaeological sites associated with prehistoric water utilization and technology is difficult. Sites are often small and can be overlooked or misinterpreted. However, an aspect of evaluating prehistoric water-management features and systems is assessing them in terms of the local and regional cultural landscape. Even if a property is not considered NRHP eligible because it lacks integrity or the potential to yield new and important information, it could be considered in terms of its local and regional socioeconomic land use patterns. Is a property associated with nearby villages, how does a given feature fit within a local system (e.g., is an identified canal segment part of a bigger canal system), what does the property tell us about how people viewed the local landscape? If water-management properties are considered as part of a larger land-use system, that system could be NRHP-eligible under Criterion C or D or both as a **district**. "For a district to retain integrity as a whole, the majority of the components that make up the district's historic character must possess integrity even if they are individually undistinguishable. In addition, the relationships among the district's components must be substantially unchanged since the period of significance" (NPS 1997:46). The boundaries of a nominated district should be defined on the basis of the shared relationship of individual sites within it. Thus, defining features in terms of a district might facilitate the NRHP nomination of a group of water-management properties not otherwise eligible.

In summary, following Doyel (1993a:53), priority of eligibility determinations should be given to prehistoric water management properties that meet the following criteria:

1. Features that possess integrity. That is, features that have not significantly impacted by post-abandonment cultural or environmental processes. Thus, features that have been eroded, disturbed, or scattered will not likely yield important information and therefore are not NRHP-eligible.

2. Features with potential to contain subsurface deposits. Information on the functioning or cultural context of any features investigated will be derived from contexts (sediments) in and/or below/behind the feature. Thus, those features that appear intact are more likely to yield materials (pollen, macrobotanical, cultural) that provide information on the types of plants grown on or near them or on their cultural and temporal contexts.

3. Features that exist as parts of intact systems. Features that are parts of intact systems, when studied collectively, have a high potential to produce important information and contribute to a better overall understanding of how a system functioned. This is mainly an issue of integrity. The more intact a system is, the greater the likelihood that the investigation of features within it will prove productive.

4. Features that can be dated. Understanding the temporal context of properties contributes significantly to our ability to interpret them within both evolutionary and cultural frameworks. Dating of these features is often problematic, in that artifacts found in association with the features or systems, even if diagnostic, may be of questionable association, and rarely do such features produce materials suitable for radiometric dating.

5. Features or systems that are associated with communities. If features or systems can be associated with nearby habitation sites, it is then possible to address the role of the features or systems within the cultural landscape of the area. Questions and research issues can move beyond the simple assessment of form and function, and broader issues regarding socioeconomic organization and land use can be addressed.

In general, if such properties are determined to be eligible, prehistoric canals and irrigation-related features should be considered important public resources that can contribute significantly to our understanding and appreciation of Arizona's past. The realization of this potential can be facilitated in several ways. First, archaeological research must continue to be conducted on canals and canal systems throughout the state. Although much progress has been made, many important questions about prehistoric canal irrigation remain (see "Data Gaps and Future Research Directions" in Chapter 7) and deserve further study. Archaeologists should utilize geoarchaeological techniques of in-field data collection and are encouraged to employ professional geomorphologists where necessary. In addition, researchers should pursue sedimentological and biological analyses of canal samples to more fully understand the operational history of canals and canal systems. These analytical techniques have become more sophisticated, and they require accurate and comprehensive in-field documentation and sampling. Moreover, it is vital that researchers interpret canals and canal systems within their broader environmental and cultural contexts (see Chapter 5). This approach entails consideration of geomorphological, climatic, hydrological, and edaphic contexts of canal systems and irrigation features, formation processes that can modify irrigation features, the context of irrigation features within the larger subsistence-settlement system. Finally, synthetic studies of canal systems (e.g., Hackbarth, Henderson, and Craig 1995; Howard and Huckleberry 1991) and intersystem comparisons are needed to provide a broader perspective on the context of irrigation in prehistoric society.

One final comment is worth making regarding the importance of the resource and research significance of a site. As Mabry (1998a:131) states, "It must be explicitly recognized that the significance of an archaeological site is a relative quality that changes in relation to two types of knowledge." First, the significance of a site changes as the known universe of sites changes, that is, as new sites are discovered and previously recorded ones deteriorate or are destroyed. Second, archaeological knowledge changes. As new discoveries and research answer old questions, they often give rise to new questions. Another aspect of this process is that as archaeologists use the ever-increasing array of technologies being developed in other disciplines, a site that would not have yielded significant new information yesterday may produce such information tomorrow. Nevertheless, assessing the research potential of a site is an integral aspect of determining NRHP eligibility.

LIST OF SITES ASSOCIATED WITH PREHISTORIC WATER UTILIZATION AND TECHNOLOGY ON THE NATIONAL REGISTER OF HISTORIC PLACES

The following list of properties listed on the NRHP was compiled from the files of the Arizona State Historic Preservation Office. The criterion or criteria under which the property was nominated was not always readily identifiable, but it is assumed that most were nominated (or are eligible) under Criterion D. Furthermore, most of the sites listed here were not specifically listed because of the presence of prehistoric water-management features but are reported to have water-management features associated with them or water-management properties occurring nearby that are likely associated with the site, or are suggested to be agricultural sites.

Table 6.1. National Register of Historic Places listed properties associated with prehistoric water technology and utilization.

Name	County	Date Listed	Criterion
Flattop Site	Apache	1976	D
Kin Tiel	Apache	1978	D
Canyon de Chelly National Monument	Apache	1986	D
Lower Zuni River Archaeological District	Apache	1994	D
Lehner Mammoth-Kill Site National Historic Landmark	Cochise	1967	D
Quibari	Cochise	1971	D
Naco Mammoth-Kill Site	Cochise	1976	D
Winona Site National Historic Landmark	Coconino	1964	D

Name	County	Date Listed	Criterion
Nuvakwewtaqa (Chavez Pass Pueblo)	Coconino	1986	D
Tutuvena Spring	Coconino	1986	D/TCP?
Willow Springs	Coconino	1986	D
Elden Pueblo	Coconino	1986	D
Winona Village Archaeological District/National Historic Landmark	Coconino	1986	D
Ridge Ruin Archaeological District	Coconino	1986	D
Walnut Canyon National Monument	Coconino	1995	D
Wapatki National Monument	Coconino	1995	D
Snake Gulch Rock Art	Coconino	1996	D
Rye Creek Archaeological District	Gila		D
Tonto National Monument	Gila	1987	D
Houston Mesa Ruins (Shoofly Village)	Gila	1989	D
Rye Creek Ruin Platform Mound Complex Archaeological District	Gila	1995	
Marijilda Canyon Prehistoric Archaeological District	Graham	1989	D
Hohokam-Pima Irrigation Site National Historic Landmark	Maricopa	1963	D
Pueblo Grande National Historic Landmark	Maricopa	1964	D
Gatlin Site National Historic Landmark	Maricopa	1964	D
Fortaleza	Maricopa	1969	D
Hohokam-Mormon Irrigation Canals	Maricopa	1975	D
Cashion Archaeological Site	Maricopa	1978	D
Mesa Grande	Maricopa	1979	D
Midvale Archaeological Site	Maricopa	1989	D
Fort McDowell Archaeological and Historic District	Maricopa	1992	D
Willimas Air Force Base	Maricopa	1995	
Grasshopper Ruin	Navajo	1978	
Homolovi I, II, IV	Navajo	1984/83/86	D
Chevelon Ruins	Navajo	1984	D
Rincon Mountain Foothills Archaeological District	Pima	1979	D
Sutherland Wash Archaeological District	Pima	1989	D
Gunsight Mountain Archaeological District	Pima	1991	D
Upper Davidson Canyon Archaeological District	Pima	1992	D
Hohokam Platform Mound Communities of the Lower Santa Cruz Basin	Pima/Pinal	1993	D
Casa Grande National Monument	Pinal	1892	D
Adamsville	Pinal	1970	D
Grewe Site	Pinal	2001	D
Perry Mesa Archaeological District	Yavapai	1975/1996	D
Hatalacva Ruin	Yavapai	1974	D
Clear Creek Pueblo and Caves	Yavapai	1975	D

CHAPTER 7

MANAGING PREHISTORIC WATER UTILIZATION AND TECHNOLOGY FEATURES AND SITES

Michael S. Foster, M. Kyle Woodson, and Gary Huckleberry

The management and preservation of features and sites representing prehistoric water use and technology is an arduous task. As Arizona's population grows, urban sprawl and increased demands directly or indirectly, intentionally, or inadvertently destroy or impact the archaeological resource base of the state, be it on private, state, or federal lands. The management and preservation of the archaeological resource base is further threatened by the ever-increasing limitations of state and federal funding for management, protection, and research.

DATA GAPS AND FUTURE RESEARCH

The last 20 years have seen an explosion in the literature regarding prehistoric water use and technology throughout Arizona, especially in the Hohokam area. However, limited study has been done along the western boundary of the state, in the Basin and Range physiography inhabited by the prehistoric Patayan, and although the presence of watermanagement features has been documented in the northern and eastern parts of the state, these areas have not seen the widespread recording and reporting of such features and sites. This lack of documentationis in part due to a general lack of extensive survey and the fact that such features and sites do not appear to be common in these areas.

An array of research questions can be posed regarding prehistoric water use and technologies that seemingly fall into two general categories: (1) the identification, recording, and study of features and technology associated with prehistoric water use; and (2) theoretical issues regarding the consequences of human interaction with and reliance on water as a resource. Although water is only one of the many resources used by prehistoric Arizonans, it is among a very few that is absolutely essential for human survival. Humans can live without turquoise or shell jewelry, and they can make use of most lithic resources that happen to be handy–water is an everyday need.

The most comprehensive research on prehistoric water use in Arizona has focused on the Hohokam, probably because of the diversity of agricultural technologies they practiced, the vicinity of the Hohokam culture area to Arizona's two largest metropolitan areas, and the rise in cultural resources management, which is often carried out on land that is to be developed. The largest data gap, which has improved slightly since the first non-irrigation agricultural SHPO context was written (Doyel 1993a), is the lack of systematic recording of agricultural features and the lack of systematic terminology to reference those features. The site cards and information, including AZSITE, on file at the Arizona State Museum and the State Historic Preservation Office show significant variation in the recording methods and terminology used in documenting agricultural sites. Site cards range from no recording of features to very precise mapping of each individual feature within a site. Adequate description of agricultural features, when they are present at archaeological sites, along with any associated features and artifacts, is essential if we are to continue to expand our understanding of prehistoric agriculture in Arizona. Moreover, the use of more systematic terminology and explicit description would greatly facilitate research.

Water-management features are not necessarily highly visible. They can easily be overlooked if the investigator is not conscious of the possibility of such features being present in the area investigated, especially if the investigator's focus is on more highly visible remains such as pueblos or ceramic/artifact scatters. These circumstances may be, in part, responsible for the lack of identification of such features in areas where they have not been extensively documented. Much more intensive identification efforts appear to be required in the western, northern, and eastern parts of the state. Also, for the most part, such features and sites are recorded in a somewhat secondary fashion. That is, rarely are they the focus of inventory surveys; instead they are more often recorded as part of a larger survey or are inadvertently discovered (e.g., canals) during exploratory or data recovery excavations that focus on some other feature types.

Another significant data gap, one that deserves a concerted effort in future research, is the dating of prehistoric water-management features and sites. It is rare that such features can be directly dated or that a relatively precise construction date can be determined. Radiometric dates are usually obtained from materials that have likely been washed in or deposited after the feature first came into use, and thus whether the material dates the beginning, middle, or end of the use of the feature is not known. Paleomagnetic dating (see Eighmy, Chapter 5) has potential, but its success in dating canal sediments is marginal. This technique can, however, be applied to other water feature types (such as reservoirs), where sediments are deposited as a result of ponding or slow water movement.

As noted in previous chapters, many of the water-management techniques known ethnographically, and undoubtedly employed prehistorically, leave no visible surface evidence. Our understanding of floodwater and inundation farming or even of some irrigated fields that may not have any discernible features, surface or buried, associated with them is also problematic. The discovery of such facilities is often fortuitous or based on an educated guess as to where such facilities might have existed. However, a recent interdisciplinary study of Hohokam field profiles might provide some direction in the identification of floodwater and other types of fields (Greenwald et al. 1996:49). An intriguing layer of particularly reddish, oxidized-looking soil was found. It was determined to have been due to factors "other than the usual pedogenic processes" and was most likely the result of agricultural activities. These results showed how agricultural practices can alter soil properties through the introduction of minerals and sediments, especially when studied diachronically in profile. This technique has not yet been widely utilized in archaeology, but it could aid in the study of agricultural practices, particularly floodwater inundation, which is otherwise archaeologically invisible (Greenwald et al. 1996; Huckleberry 1992).

Detailed sediment, pollen, and macrobotanical studies may also tell us about the ability of certain features (reservoirs, catchment basins, wells, playas) to retain water and when they held water (e.g., Bayman, Palacios-Fest, and Huckell 1997).

Canals connect the human and natural components of the landscape and are an important legacy of Arizona's past. Over 3,000 years of canal irrigation have influenced cultural history in the desert Southwest. Hundreds of miles of relict historic and prehistoric canals still remain preserved, mostly below ground surface, and contain information that can be used to address issues ranging from the sociopolitical complexity of past hydraulic societies to the resilience or vulnerability of canal irrigation to natural and anthropogenic environmental change. Further investigation of relict canal systems can help to define how these fluvial systems were constructed, operated, and abandoned, and contribute to the overall goal of understanding past desert-agricultural adaptations in Arizona. Many important questions remain and deserve further study:

1. Where and when were canals first constructed and how did they evolve through time? The earliest canals thus far identified are small systems in the Tucson Basin that date as early as

1100–1000 B.C. (Mabry 2002; Muro 1998). Larger canal systems began to be built later in time (around A.D. 100 in the Phoenix Basin and A.D. 500 in the Tucson Basin). To answer this question, it is necessary to identify more canals constructed during the Early Agricultural period. This may require excavating older stream terraces and digging to greater depths in the floodplain for remains of these early features. If more of these early water-control systems are identified and dated, then we can better evaluate how canal engineering evolved and to what degree canal irrigation was a locally developed technological innovation rather than a technology developed through diffusion from Mexico. Moreover, further information on the origin and early development of canals can be combined with existing data on better-known canal systems from later periods, facilitating synthetic studies of the evolution of canal technology through time in Arizona.

2. What are the operational characteristics of canals and canal systems? Answering this question includes assessing the hydrodynamic (e.g., flow traits, discharge, irrigable area) and environmental (e.g., salinity, seasonality of use) characteristics of canal irrigation features and canal systems. Such information represents important baseline data needed for understanding canal system operation and for making inferences on broader issues such as agricultural productivity, population size, and system efficiency. Canal morphology and sedimentology can be used to help answer questions of the flow history and depositional regimes of canals. Analysis of micro-invertebrates, pollen, and macrofossils deposited in canal sediments will together or separately be useful for revealing episodes of water flow in canals and periods of water stagnation or desiccation, and providing insight into season(s) of canal operation.

3. How did canal systems change through time? What is the magnitude of a given canal system? What is the longevity of individual canals and irrigation features within the system? Key to this question is improving the dating of canal segments and increasing the number of canals whose stratigraphy and geometry can be traced over long distances. Howard (1994) correlated distant Hohokam canal segments in Canal System 2 in the lower Salt River valley and modeled both longitudinal change and mechanisms for system growth. As more canal segments are documented, efforts should be made to correlate distant segments within single alignments in different geomorphic contexts to see how applicable Howard's model is to other prehistoric canal systems.

   One of the important points of investigation of system change is magnitude of a canal system and longevity of individual canals within a system. Research in the lower Salt Valley (e.g., Ackerly and Henderson 1989; Ackerly et al. 1987; Hackbarth et al. 1995; Howard and Huckleberry 1991), for instance, has shown that the large-scale Hohokam canal systems were not progressively elaborated through time. That is, canals were not continuously used, but rather alignments often were abandoned and rebuilt sequentially throughout the system's history. Thus, the magnitude of multi-channel systems can be overestimated by assuming that all canals were used at the same time.

4. How detrimental was flooding to the operation of canal systems? How did the frequency and magnitude of flooding change through time? Answering this question requires an ability to identify and date flood deposits in canal contexts. Canal stratigraphy and sedimentology need to be systematically described and sampled in order to construct a flood facies model that will define how flood deposits change longitudinally within canal alignments. Flood-damaged historic canals and their stratigraphy can be useful analogs for prehistoric canals (Huckleberry 1999a, 1999b). Analysis should also include deposits of the landforms containing the abandoned channels in order to better define overall geomorphic context and flood history. Importantly, investigators will need to consider and integrate dendrohydrological reconstructions of prehistoric

runoff and droughts (Ackerly 1989; Graybill et al. 1999; Nials et al. 1989) as well as alluvial stratigraphy (Huckleberry 1999a; Waters 1998; Waters and Ravesloot 2000, 2001) to develop an understanding of how dynamic hydrological processes influenced the construction, operation, and maintenance of canal systems.

5. What are the implications of the characteristics of irrigation features and canal systems for agricultural productivity, population size, labor requirements, and social organization? For example, canal discharge can be used to estimate irrigable acreage (e.g., Ackerly and Henderson 1989; Ackerly et al. 1987; Crown 1987b; Haury 1976; Howard 1994; Masse 1981). These estimates can be used in conjunction with streamflow and soil data and estimates of irrigable land and crop yield to model agricultural productivity, which, in tandem with assumptions about food consumption, may further be used to model population size (e.g., Van West and Altschul 1997; Waters 1998). Labor requirements and water-management strategies also have been assessed using data from canal features (e.g., Ackerly 1982; Ackerly et al. 1987; Haury 1976; Neitzel 1991:194–198; Nicholas and Neitzel 1984; Woodbury 1961a).

6. How do canal systems compare with each other in terms of operational history, capacity, and efficiency? Hohokam canal studies in the past few decades (e.g., Ackerly and Henderson 1989;Ackerly et al. 1987; Crown 1984a; Haury 1976; Hackbarth et al. 1995; Howard 1990; Howard and Huckleberry 1991) routinely have provided reconstructions of canal system structure and development and data on canal discharge and irrigable acreage. However, few systematic attempts have been made at intersystem studies (see Huckleberry 1999a). Cross-comparisons of canal systems in terms of operational history, capacity, and efficiency will be fruitful for attaining a broader perspective on canal irrigation technology in Arizona.

7. Was canal irrigation ecologically sustainable and to what degree did canals modify the natural environment? Evidence of soil salinity or other irrigation impacts to soil need to be documented. Stable isotope geochemistry of shell and ostracode remains in canals may provide detailed information regarding changes in both water temperature and salinity through time (Palacios-Fest 1997).

8. Further development of analog models for prehistoric canal irrigation using historic documents and physical evidence from historic and modern canals. Ackerly (1989, 1991), Adams, Smith, and Palacios-Fest (2001), and Huckleberry (1999b) have demonstrated that historic documents and physical evidence from historic and modern canals can be profitably used as analog data to validate inferences about prehistoric canal systems. Such proxy data include processes affecting the structure and operation of canal systems, such as flooding and river channel stability; canal channel characteristics, such as discharge, that affect reconstructions of water capacity and irrigable acreage; and patterns in canal fill sediment traits, such as those that can help identify destructive flooding episodes and seasonality of use. Further work can be done to integrate historic records and physical data into analog models.

9. Hydrological and biological studies of modern earthen canals for further development of analog models for prehistoric canal irrigation. Adams, Smith, and Palacios-Fest (2001:49) indicate that one potentially useful future historic analog study would include sampling actively flowing modern canals for sediments and biological organisms and recording the physical parameters of the water (i.e., water temperature, pH, conductivity, major and minor ions, streamflow velocity) to link biological assemblages to known water conditions at the time of deposition. By sampling canals in multiple season(s), the hydrologic parameters and organisms can be tied to periods of the calendar year, possibly providing distinct seasonality signatures. The nature and timing of maintenance activities, specifically focusing on use of fire to reduce canalside vegetation, might

be documented through increased charcoal in pollen samples acquired downstream from headgates where fires are still used on occasion to clear vegetation masses. Acquisition of pollen samples and vegetation lists from slightly distant terrestrial loci will continue to reveal the potential contributions of airborne and locally available pollen to the landscape, and provide baseline data for contrast with pollen within the canals. These studies should help refine the relationships between modern irrigation canals and the biological organisms and sediments within them, information that can then serve as a strong proxy record for archaeological interpretation of prehistoric canal conditions and use.

10. What are the spatial distribution and temporal and morphological variability in water-utilization features associated with canal systems? Many investigations have documented and studied such features, including reservoirs (e.g., Ackerly, Howard, and McGuire 1987), settling basins (Nials and Fish 1988), "dipping pools" (Haury 1976), and other types of garden pools (e.g., Neely 2001). However, further information is needed regarding the spatial distribution and temporal and morphological variability in these features. Specific questions to ask in the study of such features might include how long water was stored in reservoirs; analysis of biological organisms can assist in this determination (e.g., Bayman, Palacios-Fest, and Huckell. 1997).

Finally, as with everything else we study from the archaeological record, we may someday be able to utilize new technologies that will allow us to extract data currently out of our reach in the investigation of prehistoric water-management properties.

MANAGEMENT OF PREHISTORIC WATER UTILIZATION AND TECHNOLOGY PROPERTIES

Nominations

As part of the requirements for the completion of the contract associated with the production of this document, a thematic multiple property nomination has been completed, an important step in facilitating the nomination to the NRHP of eligible properties. Development of the thematic multiple property nomination for prehistoric water use and technology in Arizona provides a framework for the nomination of individual or other multiple properties. The Marana Community (Fish, Fish, and Madsen 1992a) was nominated for listing on the NRHP as part of the submission of the thematic multiple property nomination.

Inventory and Evaluation

In terms of prehistoric water use and management, there is a dearth of information from most of Arizona, with the exception of the central and southern (the Hohokam area) part of the state. Archaeologists conducting inventory surveys in the Lower Colorado River valley, the Papaguería, the Western Desert, and northern and eastern Arizona should be aware of the possibility of encountering and identifying prehistoric water-management features and systems. Any research, either inventory survey or remote sensing, oriented specifically to the location and documentation of prehistoric water-management features and sites should be encouraged.

AZSITE and the Arizona State Museum/SHPO Site Files

With AZSITE, the oversight agencies in Arizona are moving to a single site file containing the site records from across the state. AZSITE as it is now available on the World Wide Web (WWW) is of limited use. First, it does not allow significant queries of the data (site forms). Furthermore, the maps are often overlain with so much data that it is not possible to obtain the needed information, and the maps are not linked to the site form database. The Arizona SHPO has overcome many of the current obstacles. For example, the database can be queried by feature type present on a site. As part of future improvements, there must be absolute cooperation among the various agencies (state and federal) regarding access to site records.

One of the themes of this document has been standardization in terminology. It is hoped that we have clarified and standardized the nomenclature applied to prehistoric water features. It is true that there is a bit of shoehorning going on, since we are trying to apply a single scheme to a variety of culture areas. However, one of the shortcomings of using the ASM site file database is that as it now stands, it is not possible to sort, for example, prehistoric water-control features from historical ones and thus to extract the number of prehistoric water-control features from the total number of such features (prehistoric and historical). To be able to do this will certainly require restructuring of the site file database and perhaps the ASM site form. The ASM site forms and the database are riddled with inconsistencies wrought by the archaeological community. Much of this has to do with how recording site information has changed over time; some of it has to do with the constraints of time and money. Too much of it is generated by a lack of consistency among individuals and companies and the lack of a system to monitor and standardize the information as it comes in.

The Canal Maps

In 1991 Jerry Howard and Gary Huckleberry compiled data on the distribution of prehistoric canals within the Phoenix Basin. The map was produced by Soil Systems, Inc., as part of a symposium on prehistoric irrigation in Arizona (Breternitz 1991). The summary map (1:48,000) for the central Phoenix Basin is based on a series of detailed 1:24,000 topographic quadrangles that were produced in AutoCAD by GEO-MAP, Inc. (James P. Homlund) in Tucson. The maps can be obtained through either GEO-MAP or Soil Systems. More than a decade has passed since the data were compiled for these maps. The SHPO should establish a clearinghouse for compiling reports of the discovery or identification of prehistoric canal segments across the state, the Phoenix map(s) should be updated annually, and similar maps should be compiled and published for other parts of the state. Funding for such an undertaking should be sought through either grants or perhaps private donations.

Standardization of Terms

One of the problems facing those responsible for researching and managing cultural resources is the inconstant and sometimes confusing use of terms. Chapters 3 and 4 of this volume in particular provide a series of definitions relating to non-irrigation water-management and associated technologies. It has been suggested that some of the terms discussed be abandoned in favor of other terms that more accurately reflect feature or technology form or function or both. It has also been suggested that some terms be abandoned altogether because they are inappropriate for discussing agriculture and water management. The readers of this document are strongly urged to adopt the terminology set forth in this volume in an effort to standardize local and regional discussions of water-control features and technologies. If for some reason a term does not apply in a particular case or the term does not adequately identify the feature being discussed, it becomes paramount that the investigator explicitly define and describe the feature under discussion. It is of equal importance that the investigator explains how the feature deviates from a term commonly used and justify why the term applied is appropriate. Although it might seem that a movement toward standardization of terminology might mask the variability that exists between and among water-management features and technologies, it should actually bring clarity to such discussions. The goal, as they say, is to "get us all on the same page."

EDUCATION AND RECREATIONAL DEVELOPMENT

Arizona has more land within the boundaries of Native American reservations than any other state in the Union and the highest population of Native Americans. The Euroamerican population of Arizona is aware of the Native American presence in the state and is generally well aware of our rich and abundant archaeological record. The expansion of population in the state and the explosion in development have made archaeology a prominent factor in land development. This, combined with the proactive involvement of Native Americans in the protection of sacred sites and human remains, make the archaeology of Arizona a prominent political issue. Nevertheless, one of the benefits of this prominence is that it has resulted in the documentation and investigation of thousands of sites. The last several decades have produced more work than the previous century.

Most prehistoric management features and sites are not particularly spectacular. Nevertheless, there are numerous such sites that are impressive examples of how the prehistoric occupants of the state managed and manipulated water to their advantage. The bordered gardens of the Safford Valley, the check dams and contour terraces of the Point of Pines area, the rock pile and contour terrace fields of the Marana area, and the Hohokam canal systems are excellent examples of prehistoric water control. These features are manifestations of prehistoric engineering skills and they reflect the intimate knowledge of the local environments possessed by their builders. These two things alone are sufficient to instill awe and appreciation in both the professional investigator and the disinterested layperson. Thus, the prehistoric water-management sites in Arizona hold the potential to be both educational and entertaining.

More interpretive opportunities for prehistoric water-management sites should be developed. As of now, there are no agency or private initiatives to develop interpretive facilities that focus on prehistoric water management and use. Clearly, such facilities would hold great educational value. A common question from laypersons is, "How did the Native Americans live in such a harsh environment?" Until such facilities can be established, or perhaps in lieu of such facilities, displays and exhibits in museums and visitors centers could be developed throughout the state to illustrate the various prehistoric water-management technologies found here and serve as educational opportunities for the public. The SHPO might also consider assembling a traveling exhibit on the topic. Educational displays could be prepared for or by tribal entities for schools, visitor centers, and district or chapter centers. A video or interactive CD-ROM might be prepared for distribution as well. Such displays would provide information regarding what is an often overlooked or little-considered aspect of Native American prehistory in the state. A goal of this project is to place a web site about prehistoric water utilization and technology on both the SWCA and GRIC (and possibly SHPO) servers, or any other suitable public server, so that the public has ready access to such information.

Archaeologists, however, must publish their findings about Arizona's ancient irrigation works for the general public in easily understandable forms and do so in many venues. Existing museums, institutions, and programs represent the most readily available venues for public outreach. For example, exhibits on prehistoric canal irrigation can be designed and placed in museums and other public institutions, such as state and city buildings. Displays and tours of canal systems and irrigation features can be offered during Arizona Archaeology Awareness Month and at the Archaeology Expo. In addition, newspapers and popular magazines should continue to be seen as important resources for wide dissemination of interesting information and discoveries about prehistoric irrigation. Producers of public television programs can be encouraged to include features about prehistoric irrigation. Native American participation in all these endeavors also should be encouraged to provide broader perspectives on the place of irrigation in indigenous societies. Lastly, education initiatives can be designed for schools, such as providing information for inclusion in school textbooks or publishing an educational packet or pamphlet that can be handed out in schools.

NATIVE AMERICANS AND PREHISTORIC WATER-MANAGEMENT SITES

Many of the Native Americans living in Arizona are as closely tied to the land today as were their ancestors of a thousand years ago. Whether it is a traditional Hopi farmer growing crops in Moenkopi Wash or in a sand dune field on Second Mesa, or a modern Akimel O'odham (Pima) farmer driving a John Deere tractor in a field near Blackwater, many of Arizona's Native American farmers still depend on the rain to fall, the snows to melt, and the streams and rivers to flow so that the corn they planted in the spring can be eaten and stored in the fall. One of the interesting aspects of the research for this document was the review of John T. Hack's (1942) *The Changing Physical Environment of the Hopi Indians of Arizona*. In many ways it still stands as a guide to prehistoric water use and technology in Arizona. The Hopi farming techniques he discussed 50 years ago are still widely used by the Hopi today.

As Ravesloot and Woodson (2000) note, the Euroamerican (and Mexican) colonization of the southwestern United States and the subsequent confinement of Native Americans to reservations in the late 1800s significantly restricted tribal lands and limited the access of native peoples to the natural resources on which they traditionally depended, including water. The introduction of cattle and Euroamerican farming techniques, which included the diversion of large amounts of river water, brought about the desertification of the Gila River and the destruction of riverine oases. Mining polluted streams and other surface waters. As a result, many native people were plunged into famine and the loss of self-sufficiency that resulted in the near total destruction of their cultural traditions, especially in central and southern Arizona.

So, how does an understanding of prehistoric water utilization and technology apply to modern Native Americans in Arizona today? A good example comes from the GRIC south of Phoenix. The Akimel O'odham and Pee Posh (Maricopa) of the GRIC are involved in litigation to settle water-rights claims. The GRIC is also involved in a reservation wide irrigation project in conjunction with the Bureau of Reclamation (BOR). This irrigation project is, in part, being undertaken to effectively use water obtained from the water-rights settlement. Since the BOR is sponsoring a portion of the irrigation project, and federal funding is thus involved, the project is subject to Section 106 consultation. As a result, over 130,000 acres of GRIC have been surveyed for archaeological sites, and numerous sites have been tested to determine their NRHP eligibility. Additionally, a reservation-wide geomorphic study (Waters and Ravesloot 2000), a surface survey supplemented by subsurface trenching, has been completed.

The archaeological investigations on the GRIC have contributed support to the water-rights claims in several ways. One, they have demonstrated an extensive prehistoric occupation of the middle Gila River valley. Two, the archaeological and geomorphic testing conducted have added significant information regarding the extent and distribution of prehistoric canals in the valley. This work has also demonstrated that prehistoric canals coming off of the Salt River in the Phoenix Basin extended into what is now the GRIC. These canals unequivocally demonstrate that the Native American occupants of the Gila and Salt river valleys have a history of water use along these rivers that extends back over 1,000 years. Finally, the archaeological, historical, and ethnographic studies associated with both the irrigation project and the water-rights litigation have clearly established the Akimel O'odham's widespread use of their aboriginal lands. The GRIC example certainly serves as a model for other Native American groups around the state where water-rights and land-tenure issues exist.

Another interesting undertaking worth mentioning in these contexts is the fact that the Hopi are in the process of revitalizing the bordered or terrace gardens at Bacavi. These gardens are self-irrigated terraces along the mesa walls below villages where farming is made possible by the presence of perennial springs. These springs permitted settlement on the Hopi mesas. Some of the garden terraces at Bacavi have been in use since A.D. 1200. Traditional crops grown in the terrace gardens include melons and squash. This is clearly an example of an ancient agricultural and water-management practice that continues into the presence (see Hack 1942).

SELECTED BIBLIOGRAPHY

Abbott, D. R.
2000 *Ceramics and Community Organization among the Hohokam.* University of Arizona Press, Tucson

Abbott, D. R., and D. M. Schaller
1992 Exploring the Production and Social Significance of Salado Polychrome at Central Phoenix Basin Hohokam Sites. In *Proceedings of the Second Salado Conference, Globe, Arizona,* edited by R. C. Lange and S. Germick, pp. 248–258. Occasional Paper No. 1992. Arizona Archaeological Society, Phoenix.

Abruzzi, W. S.
1989 Ecology, Resource Redistribution, and Mormon Settlement in Northeastern Arizona. *American Anthropologist* 91:642–655.

Accola, R.
1981 Mogollon Settlement Patterns in the Middle San Francisco River Drainage, West-Central New Mexico. *The Kiva* 46:155–168.

Ackerly, N. W.
1982 Irrigation, Water Allocation Strategies, and the Hohokam Collapse. *The Kiva* 47:91–106.

1988 False Causality in the Hohokam Collapse. *The Kiva* 53:305–319.

1989 Paleohydrodynamic Impacts on Hohokam Irrigation Systems. In *Prehistoric Agricultural Activities on the Lehi-Mesa Terrace: Perspectives on Hohokam Irrigation Cycles*, edited by N. W. Ackerly and T. K. Henderson, pp. 46–83. Northland Research, Inc., Flagstaff

1991 Constructing Analog Models of Hohokam Irrigation. In *Prehistoric Irrigation in Arizona: Symposium 1988,* edited by Cory D. Breternitz, pp. 41–60. Soil Systems Publications in Archaeology No. 17. Phoenix.

1995 Important Variables for Prehistoric Irrigation Studies. In *Soil, Water, Biology, and Belief in Prehistoric and Traditional Southwestern Agriculture*, edited by H. W. Toll, pp. 279–288. Special Publication No. 2. New Mexico Archaeological Council, Albuquerque.

Ackerly, N., and K. Henderson (editors)
1989 *Prehistoric Agricultural Activities on the Lehi-Mesa Terrace: Perspectives on Hohokam Irrigation Cycles.* Northland Research, Inc., Tempe.

*This volume presents detailed analyses of prehistoric canals found on the Lehi-Mesa Terrace. It stands as one of the more comprehensive studies of Hohokam irrigation and provides an array of baseline information and data that can be used for comparative and analytic purposes.

Ackerly, N., J. Howard, and R. McGuire
1987 *La Ciudad Canals: A Study of Hohokam Irrigation Systems at the Community Level.* Arizona State University Anthropological Field Studies No. 17. Tempe.

Adams, E. C.
1979 Cold Air Drainage and Length of Growing Season in the Hopi Mesas Area. *The Kiva* 44:285–296.

1981 A View from the Hopi Mesas. In *The Protohistoric Period in the North American Southwest,* edited by David R. Wilcox and W. Bruce Masse, pp. 321–335. Anthropological Research Papers No. 24. Arizona State University, Tempe.

1983 The Appearance, Evolution, and Meaning of the Katsina Cult to the Pre-Hispanic Pueblo World of the Southwestern United States. Paper presented at the 11th International Congress of Anthropological and Ethnological Sciences, Vancouver.

Adams, I. H.
1976 *Agrarian Landscape Terms: A Glossary for Historical Geography.* Special Publication No. 9. Institute of British Geographers, London.

Adams, K. R., S. J. Smith, and M. R. Palacios-Fest
2001 *Pollen and Micro-Invertebrates from Modern Earthen Canals and Other Fluvial Environments along the Middle Gila River, Central Arizona: Implications for Archaeological Interpretation.* P-MIP Technical Report No. 2001–02. Cultural Resource Management Program, Gila River Indian Community, Sacaton.

Adams, R. McC.
1966 *The Evolution of Urban Society: Early Mesopotamia and Prehispanic Mexico.* Aldine Press, Chicago.

1971 Developmental Stages in Ancient Mesopotamia. In *Prehistoric Agriculture,* edited by Stuart Struever, pp. 572–590. Natural History Press, Garden City, New York.

Agenbroad, L. D.
1967 The Distribution of Fluted Points in Arizona. *The Kiva* 32:113–120.

Agenbroad, L. D., C. Vance Haynes, and G. Kelso
1972 The Clovis Hunting Camp at Murray Springs, Arizona: An Analysis after Two Field Seasons. Paper presented at the 37th Annual Meeting of the Society for American Archaeology, Miami Beach.

Agenbroad, L. D., and B. Huckell
n.d. New Discoveries at the Lehner Site: 1975–1976 and 1980. In Clovis Hunters in the San Pedro Valley, Arizona, edited by C. Vance Haynes. Ms. on file, Department of Anthropology, University of Arizona, Tucson.

Ahlstrom, R.V.N.
2000 Effective Environment of the Western PapaguerPa. In *Living in the Western PapaguerPa: An Archaeological Overview of the Barry M. Goldwater Air Force Range in Southwestern Arizona,* edited by Richard V. N. Ahlstrom. SWCA Cultural Resource Management Report No. 98-186. Tucson.

*Ahlstrom presents an in depth and extremely useful discussion of water technology and sources in the arid Papaguería.

Altschul, J., and C. Van West
1992 Agricultural Productivity Estimates for the Tonto Basin, A.D. 740–1390. In *Proceedings of the Second Salado Conference,* edited by R. Lange and S. Germick, pp. 172–182. Arizona Archaeological Society, Phoenix.

Anderson, B. (compiler)
1990 *The Wupatki Archeological Inventory Survey Project: Final Report.* Professional Paper No. 35. USDI National Park Service, Southwest Cultural Resources Center, Santa Fe.

*This report presents discussions of prehistoric agriculture in the Wupatki National Monument area, describing field systems, agricultural features and techniques, and the evolution of local agricultural systems.

Anderson, E. A.
1954 Maize in the Southwest. *Landscape* 3:26–28.

Antieau, J. M.
1981 *The Palo Verde Archaeological Investigations. Hohokam Settlement at the Confluence: Excavations along the Palo Verde Pipeline.* Research Paper No. 20. Museum of Northern Arizona, Flagstaff.

Arden, H.
1989 Who Owns Our Past? *National Geographic* 175:376–393.

Arizona State Parks
1991 Request For Proposal. Prehistoric Non-Irrigated Agriculture in Arizona: A Historic Context for Planning. Ms. on file, Arizona State Parks, Phoenix.

Ayres, J.
1967 A Prehistoric Farm Site near Cave Creek, Arizona. *The Kiva* 32: 106–111.

AZSITE
1989 AZSITE Archaeological Computer Data Base, Arizona State Museum, University of Arizona.

2001 AZSITE Archaeological Computer Data Base, Arizona State Museum, University of Arizona

Bair, G. A., and K. W. Stoker
1994 *Across the Colorado Plateau: Anthropological Studies for the Transwestern Pipeline Expansion Project, Vol. 13: Excavations of Cohonina and Cerbat Sites in the Western Arizona Uplands.* Office of Contract Archeology and Maxwell Museum of Anthropology, University of New Mexico, Albuquerque.

Bandelier, A. F.
1892 *Final Report of Investigations among the Indians of the Southwestern United States Carried on Mainly in the Years 1880 to 1885.* Papers of the Archaeological Institute of America, American Series, Vol. 4., Pt. 2. J. Wilson and Son, Cambridge.

Barton, C. E., M. W. McElhinny, and D. J. Edwards
1980 Laboratory Studies of Depositional DRM. *Geophysical Journal of the Royal Astronomical Society* 61:355–377.

Barton, C. E., and P. L. McFadden
1996 Inclination Shallowing and Preferred Transitional VGP Paths. *Earth and Planetary Science Letters* 140:147–157.

Basso, K. H.
1983 Western Apache. In *Southwest,* edited by A. Ortiz, pp. 462–488. Handbook of North American Indians, vol. 10, W. C. Sturtevant, general editor. Smithsonian Institution, Washington, D.C.

Basso, K. H., and M. H. Opler
1971 *Apachean Culture History and Ethnology.* Anthropological Papers No. 21. University of Arizona Press, Tucson.

Batt, C. M., and M. Noel
1991 Magnetic Studies of Archaeological Sediments. In *Archaeological Sciences 1989*, edited by P. Budd, B. Chapman, C. Jackson, R. Janaway, and B. Ottaway, pp 234–241. Oxford Books, Oxford.

Bayham, F. E., D. H. Morris, and M. S. Shackley
1986 *Prehistoric Hunter-Gatherers of South Central Arizona: The Picacho Reservoir Archaic Project.* Anthropological Field Studies No. 13. Office of Cultural Resource Management, Department of Anthropology, Arizona State University, Tempe.

Bayman, J. M.

1992 Hohokam Reservoirs and Their Role in an Ancient Desert Economy. *Archaeology in Tucson* 6:1–4. Center for Desert Archaeology, Tucson.

1993 Hohokam Reservoirs and Sedentism in the Interior Sonoran Desert. In *The Northern Tucson Basin Survey: Research Directions and Background Studies*, edited by J. H. Madsen, P. R. Fish, and S. K. Fish, pp: 143–157. Arizona State Museum Archaeological Series No. 182. University of Arizona, Tucson.

*One of the more comprehensive discussions of prehistoric reservoirs in the Hohokam area.

1997 Water Storage in Prehistoric Papaguería and the Limitations of Ethnographic Analogy. In *Prehistory of the Borderlands*, edited by J. Carpenter and G. Sanchez, pp. 84–93. Arizona State Museum Archaeological Series No. 186. University of Arizona, Tucson.

Bayman, J. M., and S. K. Fish

1992 Reservoirs and Locational Shifts in Sonoran Desert Subsistence. In *Research in Economic Anthropology,* edited by R Hawkins. JAI Press, Greenwich. In press.

Bayman, J. M., M. R. Palacios-Fest, and L. W. Huckell

1997 Botanical Signatures of Water Storage Duration in a Hohokam Reservoir. *American Antiquity* 62:103–111.

Beaglehole, E.

1937 *Notes on Hopi Economic Life.* Yale University Publications in Anthropology No. 2. New Haven.

Bearden, S.

1984 *A Study of Basketmaker II Settlement on Black Mesa, Arizona: Excavations 1973–1979.* Center for Archaeological Investigations No. 44. Southern Illinois University, Carbondale.

Bellah, R. N.

1970 *Beyond Belief: Essays on Religion in a Post-traditional World.* Harper and Row, New York.

Berlin, G., R. Ambler, R. Hevly, and G. Schaber

1977 Identification of a Sinagua Agricultural Field by Aerial Thermography, Soil Chemistry, Pollen/Plant Analysis, and Archaeology. *American Antiquity* 42:588–600.

Berlin, G. L., D. E. Salas, and P. R. Geib

1990 A Prehistoric Sinagua Agricultural Site in the Ashfall Zone of Sunset Crater, Arizona. *Journal of Field Archaeology* 17:1–26.

Bernard-Shaw, M.

1988 Hohokam Canal Systems and Late Archaic Wells: The Evidence from the Los Morteros Site. In *Recent Research on Tucson Basin Prehistory: Proceedings of the Second Tucson Basin Conference,* edited by W. H. Doelle and P. R. Fish, pp. 153–174. Anthropological Papers No. 10. Institute for American Research, Tucson.

1989 *Archaeological Investigations at Los Morteros, AZ 4.4:12:57(ASM), Locus 1, in the Northern Tucson Basin.* Technical Report No. 87-8. Institute for American Research, Tucson.

1990a *Archaeological Investigations at the Lonetree Site, AA:12:149(ASM), in the Northern Tucson Basin.* Technical Report No. 89-8. Center for Desert Archaeology, Tucson.

1990b Experimental Agave Fiber Extraction. In *Rincon Phase Seasonal Occupation in the Northern Tucson Basin,* edited by M. Bernard-Shaw and F. Huntington, pp. 191–196. Center for Desert Archaeology Technical Report No. 90-2. Tucson.

Berry, C. F., and M. Berry
1986 Chronological and Conceptual Models of the Southwest Archaic. In *Anthropology of the Desert West: Essays in Honor of Jesse D. Jennings,* edited by C. Condie and D. Fowler, pp. 253–327. University of Utah Anthropological Papers No. 110. Salt Lake City.

Berry, C. F., and W. M. Marmaduke
1982 *The Middle Gila Basin: An Archaeological and Historical Overview.* Northland Research, Inc., Flagstaff.

Betancourt, J.
1990 *Tucson's Santa Cruz River and the Arroyo Legacy.* Unpublished Ph.D. Dissertation. University of Arizona, Tucson.

Black, A. T., and M. Green
1995 *The San Carlos Reservoir Cultural Resources Survey.* Cultural Resources Report No. 87. Archaeological Consulting Services, Ltd., Tempe.

Boers, T. M., and J. Ben-Asher
1982 A Review of Rainwater Harvesting. *Agricultural Water Management* 5:145–158.

Boggs, S., Jr.
1995 *Principles of Sedimentology and Stratigraphy.* 2nd ed. Prentice Hall, Englewood Cliffs, New Jersey.

Bohrer, V.
1962 Ethnobotanical Materials from Tonto National Monument. In *Archaeological Studies at Tonto National Monument,* edited by L. Caywood, pp. 75–114. Southwestern Monuments Association Technical Series No. 2. Globe.

1970 Ethnobotanical Aspects of Snaketown: A Hohokam Village in Southern Arizona. *American Antiquity* 35: 413–430.

Bolton, H. E.
1936 *Rim of Christendom: A Biography of Eusebio Francisco Kino, Pacific Coast Pioneer.* Macmillan, New York.

1948 *Kino's Historical Memoir of Pimeria Alta.* 2 vols. University of California Press, Berkeley.

Boserup, E.
1965 *The Conditions for Agricultural Growth: The Economics of Agrarian Change under Population Pressure.* Aldine, Chicago.

Botsford, M., and G. Kinkade
1993 Cultural Resources Assessment of the BLM Safford District Office Project. Ms. on file, USDI Bureau of Land Management, Safford District, Safford, Arizona.

Bradfield, M.
1971 *The Changing Pattern of Hopi Agriculture.* Royal Anthropological Institute of Great Britain and Ireland Occasional Paper No. 30. London.

Brandes, R.
1957a An Archaeological Survey within Gila County, Arizona. Ms. on file, Arizona State Museum, Tucson.

1957b An Early Ballcourt near Globe, Arizona. *The Kiva* 23:10–11.

Bremer, J. M.
1989 *Walnut Canyon, Settlement and Land Use. The Arizona Archaeologist* No. 23.

Breternitz, C. D. (editor)
1991 *Prehistoric Irrigation in Arizona: Symposium 1988.* Publication in Archaeology No. 17. Soil Systems, Inc., Phoenix.

*This volume contains nine useful articles on Hohokam irrigation in central and southern Arizona.

Breternitz, D. A.
1957a 1956 Excavations near Flagstaff: Part 1. *Plateau* 30:22–30.

1957b 1956 Excavations near Flagstaff: Part II. *Plateau* 30:43–54.

1959 *Excavations at Nantack Village, Point of Pines, Arizona.* Anthropological Papers No. 1. University of Arizona, Tucson.

1960 *Excavations at Three Sites in the Verde Valley, Arizona.* Bulletin No. 34. Museum of Northern Arizona, Flagstaff.

Bronitsky, G., and J. D. Merritt
1986 *The Archaeology of Southeast Arizona: A Class I Cultural Resource Inventory.* Cultural Resource Series Monograph No. 2. USDI Bureau of Land Management, Arizona State Office, Phoenix.

Brooks, D., and R. G. Vivian
1978 *An Archaeological Investigation of the Queen Creek Floodway Project.* 2nd ed. Archaeological Series No. 66. Arizona State Museum, University of Arizona, Tucson.

Brown, J. L.
1973 *The Origin and Nature of the Salado: Evidence from the Safford Valley, Arizona.* Unpublished Ph.D. dissertation, Department of Anthropology, University of Arizona, Tucson.

Broyles, B.
1996 Surface Water Resources for Prehistoric Peoples in Western PapaguerPa of the North American Southwest. *Journal of Arid Environments* 33:483–495.

*A basic reference on water source types in the Papaguería.

Bruder, J. S.
1983 *Archaeological Investigations at the Adobe Dam Alternative Site No. 4, Phoenix, Arizona.* Research Paper No. 27. Museum of Northern Arizona, Flagstaff.

Bruder, J. S., E. J. Bassett, and A. E. Gogee
1989 *Cultural Resources Technical Report for the AT&T Communications Fiber Optic Project between Flagstaff, Arizona and Las Vegas, Nevada: The Arizona Segment.* Dames and Moore, Phoenix.

Bruins, H. J., M. Evenari, and U. Nessler
1986 Rainwater-harvesting Agriculture for Food Production in Arid Zones: The Challenge of the African Famine. *Applied Geography* 6:13–32.

Bryan, K.
1925 *The Papago Country, Arizona: A Geographic, Geologic, and Hydrologic Reconnaissance with a Guide to Desert Watering Places.* U.S. Geological Survey Water-Supply Paper No. 499. U.S. Government Printing Office, Washington, D.C.

1929 Floodwater Farming. *Geographical Review* 19: 444–456.

Bubemyre, T., M. Brodbeck, and R. B. Neily

1998 *A Cultural Resources Survey of the Borderlands Area, Gila River Indian Community, Maricopa County, Arizona.* CRMP Technical Report No. 97-23. Cultural Resource Management Program, Gila River Indian Community, Sacaton.

Burrus, E. J.

1971 *Kino and Manje: Explorers of Sonora and Arizona.* Sources and Studies for the History of the Americas No. 10. Jesuit Historical Institute, Rome and St. Louis.

Busch, C. L., M. Raab, and R. Busch

1976 Q=AV: Prehistoric Water Canals in Southern Arizona. *American Antiquity* 41:531–534.

Buskirk, W.

1986 *The Western Apache: Living with the Land before 1950.* University of Oklahoma Press, Norman.

Cable, J., and D. Doyel

1985 Hohokam Land-Use Patterns along the Terraces of the Lower Salt River Valley: The Central Phoenix Project. In *Proceedings of the 1983 Hohokam Symposium,* edited by A. Dittert and D. Dove, pp. 263–310. Arizona Archaeological Society Occasional Paper No. 2. Phoenix.

1987 Pioneer Period Village Structure and Settlement Pattern in the Phoenix Basin. In *The Hohokam Village: Site Structure and Organization,* edited by D. E. Doyel, pp. 21–70. American Association for the Advancement of Science, Glenwood Springs, Colorado.

Cable, J. S., S. L. Henry, and D. E. Doyel (editors)

1982 *City of Phoenix Archaeology of the Original Townsite: Blocks I and 2.* Publications in Archaeology No. 1. Soil Systems, Inc., Phoenix.

Cable, J. S., and D. R. Mitchell

1988 La Lomita PequeZa in Regional Perspective. In *Excavations at La Lomita PequeZa, a Santa Cruz–Sacaton Phase Hamlet in the Salt River Valley,* edited by Douglas R. Mitchell, pp. 395–446. Publications in Archaeology No. 10. Soil Systems, Inc., Phoenix.

1991 Settlement Growth and Integration in a Large Hohokam Canal System. In *Prehistoric Irrigation in Arizona: Symposium 1988,* edited by Cory Dale Breternitz, pp. 89–106. Soil Systems Publications in Archaeology No. 17. Soil Systems, Inc., Phoenix.

Canouts, V. (assembler)

1975 *An Archaeological Survey of the Orme Reservoir.* Arizona State Museum Archaeological Series No. 92. Tucson.

Cantley, G.

1991 Archaeology of a Rock Pile Site in the Santan Mountains. Unpublished Master's thesis, Department of Anthropology, Arizona State University, Tempe.

Carneiro, R. L.

1970 A Theory of the Origin of the State. *Science* 169:733–73 8.

Cartledge, T. R.

1979 Cohonina Adaptation to the Coconino Plateau: A Re-evaluation. *The Kiva* 44:297–317.

Castetter, E. F., and W. H. Bell

1942 *Pima and Papago Indian Agriculture.* Inter-American Studies I. University of New Mexico Press, Albuquerque.

1951 *Yuman Indian Agriculture: Primitive Subsistence on the Lower Colorado and Gila Rivers.* Inter-American Studies III. University of New Mexico Press, Albuquerque.

*These are primary and useful ethnographic sources on O'odham and Yuman groups of the Gila River valley and southern Arizona. The discussions of subsistence and non-irrigationd agriculture provide baseline information for archaeological interpretation.

Castetter, E. F., W. H. Bell, and A. R. Grove
1938 *Ethnobotanical Studies of the American Southwest VI. The Early Utilization and Distribution of Agave in the American Southwest.* University of New Mexico Bulletin. University of New Mexico, Albuquerque.

Chenault, M. L.
1996 The Hohokam Post-Classic Polvor6n Phase. In *The Sky Harbor Project, Early Desert Farming and Irrigation Settlements: Archaeological Investigations in the Phoenix Sky Harbor Center, Special Studies, Synthesis, and Conclusions,* edited by D. H. Greenwald and J. H. Ballagh, pp. 117–140. SWCA Anthropological Research Paper No. 4, Vol. 4. Flagstaff and Tucson.

Ciolek-Torrello, R.
1995 The Houghton Road Site, the Agua Caliente Phase, and the Early Formative Period in the Tucson Basin. *Kiva* 60:531–574.

1998 *Early Farmers of the Sonoran Desert: Archaeological Investigations at the Houghton Road Site, Tucson, Arizona.* Technical Series No. 72. Statistical Research, Inc., Tucson.

Ciolek-Torrello, R., and F. Nials
1987 Red Rock Reservoir, NA 18,022. In *Hohokam Settlements along the Slopes of the Picacho Mountains, Tucson Aqueduct Project: The Pichacho Area Sites,* edited by R. Ciolek-Torrello, pp. 265–293. Research Paper No. 35, Vol. 3. Museum of Northern Arizona, Flagstaff.

Ciolek-Torrello, R. S., S. D. Shelley, J. H. Altschul, and J. R. Welch
1990 *The Roosevelt Rural Sites Study: Research Design.* Technical Series No. 28, Vol. 1. Statistical Research, Inc., Tucson.

Ciolek-Torrello, R. S., S. D. Shelley, and S. Benaron (editors)
1994 *The Roosevelt Rural Sites Study: Prehistoric Settlements in the Tonto Basin.* Technical Series No. 28, Vol. 2. Statistical Research, Inc., Tucson.

Ciolek-Torrello, R. S., and D. R. Wilcox (editors)
1988 *Hohokam Settlement along the Slopes of the Picacho Mountains, Tucson Aqueduct Project: Synthesis and Conclusions.* Research Paper No. 35, Vol. 6. Museum of Northern Arizona, Flagstaff.

Clark, A. J.
1979 Archaeomagnetic Dating. In *Three Surrey Hillforts: Excavations at Astiebury, Holmbury and Hascombe, 1972–1977,* edited by F. H. Thompson. *Antiquaries Journal* 59:245–318.

Clark, C. P. (compiler)
2000 *Archaeological Investigations at AZ V:13:201, Town of Kearny, Pinal County, Arizona.* Cultural Resources Report No. 114. Archaeological Consulting Services, Ltd., Tempe

Clark, J. J. (editor)
2002 *Archaeological Investigations along the Gila River in the Safford Basin.* Anthropological Papers No. 39. Center for Desert Archaeology, Tucson. In preparation.

Clark, J. J., M. K. Woodson, and M. C. Slaughter

1999 Those Who Went to the Land of the Sun: Puebloan Migrations into Southeastern Arizona. In *The Archaeology of a Land Between: Regional Dynamics in the Prehistory and History of Southeastern Arizona,* edited by H. D. Wallace. Amerind Foundation and University of New Mexico Press. In press.

Colton, H. S.

1932 *A Survey of the Prehistoric Sites in the Region of Flagstaff, Arizona.* Bureau of American Ethnology Bulletin No. 104. Washington, D.C.

1939a *Prehistoric Culture Units and Their Relationships in Northern Arizona.* Bulletin No. 17. Museum of Northern Arizona, Flagstaff.

1939b*An Archaeological Survey of Northwestern Arizona Including the Descriptions of Fifteen New Pottery Types.* Bulletin No. 16. Museum of Northern Arizona, Flagstaff.

1946 *The Sinagua: A Summary of the Archaeology of the Region of Flagstaff, Arizona.* Bulletin No. 22. Museum of Northern Arizona, Flagstaff.

1958 *Pottery Types of the Southwest: Wares 14, 15, 16, 17, 18.* Ceramic Series No. 3D. Northern Arizona Society of Science and Art, Museum of Northern Arizona, Flagstaff.

1960 *Black Sand.* University of New Mexico Press, Albuquerque.

Conyers, L. B.

1998 Ground-Penetrating Radar Techniques and Three-Dimensional Mapping in the American Southwest. *Journal of Field Archaeology* 25:417–430.

1999 Geophysics, Ground-Penetrating Radar, and Archaeology. *SAA Bulletin* 17:26–29.

Cordell, L.

1984 *Prehistory of the Southwest.* Academic Press, New York.

1997 *Archaeology of the Southwest.* 2nd ed. Academic Press, San Diego.

Cordell, L. S., D. E. Doyel, and K. W. Kintigh

1994 Processes of Aggregation in the Prehistoric Southwest. In *Themes in Southwest Prehistory,* edited by G. J. Gumerman, pp. 109–133. School of American Research Press, Santa Fe.

Craig, D. B.

1988 *Archaeological Investigations at AA:16:49(ASM): The Dakota Wash Mitigation.* Anthropology Series Archaeological Report No. 14. Pima Community College, Tucson.

1989 *Archaeological Testing at Honey Bee Village (AZ BB:9:88 ASM).* Technical Report No. 89-6. Institute for American Research, Tucson.

1995 The Social Consequences of Irrigation Agriculture: A Perspective from Meddler Point. In *The Roosevelt Community Development Study: New Perspectives on Tonto Basin Prehistory*, edited M. D. Elson, M. T. Stark, and D. A. Gregory, pp. 227–249. Anthropological Papers No. 15. Center for Desert Archaeology, Tucson.

2000 Rewriting Prehistory in the Hohokam Heartland. *Archaeology Southwest* 14:1–4. Center for Desert Archaeology, Tucson.

Craig, D. B., and D.V.M. Stephen
1985 Archaeological Investigations in the Eastern Tortolitas: Results of Phase III of Tortolita Mountains Archaeological Project. Ms. on file, Pima Community College Center for Archaeological Field Training, Tucson.

Craig, D. B., and H. D. Wallace
1987 *Prehistoric Settlement in the Cañada del Oro Valley, Arizona: The Rancho Vistoso Survey Project.* Anthropological Papers No. 8. Institute for American Research, Tucson.

Crary, J. S.
1995 Previous Research. In *The San Carlos Reservoir Cultural Resources Survey*, edited by A. T. Black and M. Green, pp. 5–24. Cultural Resources Report No. 87, Vol. 1. Archaeological Consulting Services, Ltd., Tempe.

Crary, J. S., S. Germick, and D. E. Doyel
2001 Exploring the Gila Horizon. *Kiva* 66:407–445.

Creer, K. M., R. Thompson, L. Molneux, and F. J. H. Mackereth
1972 Geomagnetic Secular Variation Recorded in the Stable Magnetic Remanence of Recent Sediments. *Earth and Planetary Science Letters* 14:115–127.

Crown, P.
1983 Field Houses and Farmsteads in South-Central Arizona. In *Hohokam Archaeology along the Salt-Gila Aqueduct,* edited by L. Teague and P. Crown, pp. 3–22. Arizona State Museum Archaeological Series No. 150, Vol. 9. Tucson.

1984a Prehistoric Agricultural Technology in the Salt-Gila Basin. In *Hohokam Archaeology along the Salt-Gila Aqueduct,* edited by L. Teague and P. Crown, pp. 207–259. Arizona State Museum Archaeological Series No. 150, Vol. 7. Tucson.

1984b Adaptation through Diversity: An Examination of Population Pressure and Agricultural Technology in the Salt-Gila Basin. In *Prehistoric Agricultural Strategies in the Southwest,* edited by S. K. Fish and P. R. Fish, pp. 5–26. Anthropological Research Papers, Arizona State University, Tempe.

1985 Morphology and Function of Hohokam Small Structures. *The Kiva* 50:75–94.

1987a Water Storage in the Prehistoric Southwest. *The Kiva* 52:209–228.

*An important discussion of prehistoric water storage in the Southwest with references to Arizona.

1987b Classic Period Hohokam Settlement and Land Use in the Casa Grande Ruins Area, Arizona. *Journal of Field Archaeology* 14:147–162.

*A basic reference on prehistoric irrigation and land use in the Middle Gila River valley.

1991 The Hohokam: Current Views of Prehistory and the Regional System. In *Chaco and Hohokam: Prehistoric Regional Systems in the American Southwest,* edited by P. L. Crown and W. J. Judge, pp. 135–157. School of American Research Press, Santa Fe.

1994 *Ceramics and Ideology: Salado Polychrome Pottery.* University of New Mexico Press, Albuquerque.

Crown, P. L., and W. J. Judge (editors)
1991 *Chaco and Hohokam: Prehistoric Regional Systems in the American Southwest.* School of American Research Press, Santa Fe.

Cummings, B.
1910 *The Ancient Inhabitants of the San Juan Valley.* Bulletin Vol. 3, No. 3, Part 2, Second Archaeological Number. University of Utah, Salt Lake City.

1926 Ancient Canals of the Casa Grande. *Progressive Arizona* 3: 9–10, 43.

*A classic study of prehistoric canals in the Middle Gila River valley.

Cushing, F. H.
1920 *Zuni Breadstuff.* Indian Notes and Monographs No. 8. New York.

Czaplicki, J. S. (compiler)
1984 *A Class III Survey of the Tucson Aqueduct Phase A Corridor, Central Arizona Project: An Intensive Archaeological Survey in the Lower Santa Cruz River Basin, Picacho Reservoir to Rillito, Arizona.* Archaeological Series No. 165. Arizona State Museum, University of Arizona, Tucson.

Czaplick [illegible] rs)
1989 *Hohokam Archaeology along Phase B of the Tucson Aqueduct, Central Arizona Project: Syntheses and Interpretations.* Archaeological Series No. 178, Vol. 1. Arizona State Museum, University of Arizona, Tucson.

Danson, E. B.
1957 *An Archaeological Survey of West Central New Mexico and East Central Arizona.* Papers of the Peabody Museum of Archaeology and Ethnology No. 44. Harvard University, Cambridge.

Dart, A.
1983a Agricultural Features. In *Hohokam Archaeology along the Salt-Gila Aqueduct, Central Arizona Project: Specialized Activity Sites,* edited by Lynn S. Teague and Patricia L. Crown, pp. 345–655. Archaeological Series No. 150, Vol. 3. Arizona State Museum, University of Arizona, Tucson.

1983b *Water and Transmission Line Archaeological Surveys for the Indian Health Service at San Simon, Anegam, and Little Tucson, Papago Indian Reservation, Pima County, Arizona.* Arizona State Museum, University of Arizona, Tucson. Submitted to U.S. Indian Health Service San Xavier Agency, Tucson.

1985 *Santa Cruz River Stabilization at Valencia Road: Archaeological Testing at the Valencia Site.* Technical Report No. 85-2. Institute for American Research, Tucson.

1986a *Archaeological Investigations at La Paloma: Archaic and Hohokam Occupations at Three Sites in the Northeastern Tucson Basin, Arizona.* Anthropological Papers No. 4. Institute for American Research, Tucson.

1986b Sediment Accumulation along Hohokam Canals. *The Kiva* 51:63–84.

1989 *Prehistoric Irrigation in Arizona: A Context for Canals and Related Cultural Resources.* Center for Desert Archaeology Report No. 89-7. Tucson.

Dart, A., S. Lekson, and H. Wallace
1989 *Historic Properties Management Plan for the U.S. Army Corps of Engineers Painted Rock Reservoir Project, Southwestern Arizona.* Technical Report No. 88-6. Institute for American Research, Tucson.

Deagan, K. A.
1988 Neither History nor Prehistory: The Questions that Count in Historical Archaeology. *Historical Archaeology* 22:7–12.

Dean, J. S.

1991 Thoughts on Hohokam Chronology. In *Exploring the Hohokam: Prehistoric Desert Peoples of the American Southwest,* edited by G. J. Gumerman, pp. 61–149. Amerind Foundation New World Studies Series No. 1. Amerind Foundation, Dragoon, Arizona, and University of New Mexico Press, Albuquerque.

1992 Environmental Factors in the Evolution of the Chacoan Sociopolitical System. In *Anasazi Regional Organization and the Chaco System,* edited by David Doyel, pp. 35–43. Maxwell Museum Papers in Anthropology No. 5. Albuquerque.

2000 Introduction. In *Salado,* edited by Jeffrey S. Dean, pp. 3–16. An Amerind Foundation Publication, Dragoon, Arizona. University of New Mexico Press, Albuquerque.

Dean, J. S. (editor)

2000 *Salado.* An Amerind Foundation Publication, Dragoon, Arizona. University of New Mexico Press, Albuquerque.

Debowski, S., A. George, R. Goddard, and D. Mullon

1976 *An Archaeological Survey of the Buttes Reservoir.* Arizona State Museum Archaeological Series No. 93. Tucson.

Diehl, M.

1995 The Intensity of Maize Processing and Production in Upland Mogollon Pithouse Villages A.D. 200–1000. *American Antiquity* 61:102–115.

Di Peso, C. C.

1956 *The Upper Pima of San Cayetano del Tumacacori.* Amerind Foundation Papers No. 7. Dragoon, Arizona.

1958 *The Reeve Ruin of Southeastern Arizona: A Study of a Prehistoric Pueblo Migration into the Middle San Pedro Valley.* Amerind Foundation Papers No. 8. Dragoon, Arizona.

Doak, D. P., G. R. Seymour, S. B. Bierer, and L. Myers

1994 Site Descriptions. In *The Sanchez Copper Project: Archaeological Investigations in the Safford Valley, Graham County, Arizona,* edited by G. R. Seymour, Richard V. N. Ahlstrom, and David P. Doak, pp. 4.1–4.120. SWCA Archaeological Report No. 94-82, Vol. 1. Tucson.

Dobyns, H. F.

1963 Indian Extinction in the Middle Santa Cruz River Valley, Arizona. *New Mexico Historical Review* 38:163–181.

1974 The Kohatk: Oasis and Ak-Chin Horticulturalists. *Ethnohistory* 21:317–327.

1981 *From Fire to Flood: Historic Human Destruction of Sonoran Desert Riverine Oases.* Balena Press No. 20. Socorro, New Mexico.

Doelle, W. H.

1976 *Desert Resources and Hohokam Subsistence: The Conoco Florence Project.* Arizona State Museum Archaeological Series No. 103. University of Arizona, Tucson.

1981 The Gila Pima in the Late Seventeenth Century. In *The Protohistoric Period in the American Southwest, A.D. 1450–1700,* edited by David R. Wilcox and W. Bruce Masse, pp. 57–70. Anthropological Research Papers No. 29. Arizona State University, Tempe.

1984 The Tucson Basin during the Protohistoric Period. *The Kiva* 49:195–211.

1985 *Excavations at the Valencia Site, A Preclassic Hohokam Village in the Southern Tucson Basin.* Anthropological Papers No. 3. Institute for American Research, Tucson.

1997 Hidden Times: The Archaeology of the Tortolita Phase. *Archaeology in Tucson* 11:1–5.

Doelle, W. H., J. J. Clark, and M. C. Slaughter
1997 Demographic Issues in Southeast Arizona Prehistory. In *The Archaeology of a Land Between: Regional Dynamics in the Prehistory and History of Southeastern Arizona,* edited by H. D. Wallace. Amerind Foundation, Dragoon, Arizona, and University of New Mexico Press. In preparation.

Doelle, W. H., A. Dart, and H. D. Wallace
1985 *The Southern Tucson Basin Survey: Intensive Survey along the Santa Cruz River.* Institute for American Research Technical Report No. 85-3. Tucson.

Doelle, W. H., F. W. Huntington, and H. D. Wallace
1987 Rincon Phase Community Reorganization in the Tucson Basin. In *The Hohokam Village: Site Structure and Organization,* edited by D. E. Doyel, pp. 71–95. American Association for the Advancement of Science, Glenwood Springs, Colorado.

Doelle, W. H., and H. D. Wallace
1986 *Hohokam Settlement Patterns in the San Xavier Project Area, Southern Tucson Basin.* Technical Report No. 84-6. Institute for American Research, Tucson.

1991 The Changing Role of the Tucson Basin in the Hohokam Regional System. In *Exploring the Hohokam: Prehistoric Desert Peoples of the American Southwest,* edited by G. J. Gumerman, pp. *279–345.* New World Studies Series No. 1. Amerind Foundation, Dragoon, Arizona, and University of New Mexico Press, Albuquerque.

Donkin, R. A.
1979 Agricultural Terracing in the Aboriginal New World. Viking Fund Publications in Anthropology No. 56. Wenner-Gren Foundation for Anthropological Research, Inc., New York.

*A useful comparative study of agricultural terracing in the New World. The Southwestern U.S. is briefly discussed; the emphasis is on Mesoamerica and South America. Nevertheless, the volume provides an interesting comparative study that helps to appreciate the scale and scope of prehistoric terracing in the New World.

Doolittle, W. E.
1984 Agricultural Change as an Incremental Process. *Annals of the American Association of Geographers 74:124–137.*

1985 The Use of Check Dams for Protecting Downstream Agricultural Lands in the Prehistoric Southwest: A Contextual Analysis. *Journal of Anthropological Research* 41:279–305.

1988a *Pre-hispanic Occupance in the Valley of Sonora, Mexico: Archaeological Confirmation of Early Spanish Reports.* Anthropological Papers No. 48. University of Arizona Press, Tucson.

1988b In Tlaloc They Did not Trust: The Development of Canal Irrigation Technology in Prehistoric Mexico. Ms. on file, Department of Geography, University of Texas, Austin.

1990 Canal Irrigation in Prehistoric Mexico. University of Texas Press, Austin.

1991 A Finger on the Hohokam Pulse. In *Prehistoric Irrigation in Arizona: Symposium 1988,* edited by C. D. Breternitz, pp. 139–154. Publications in Archaeology No. 17. Soil Systems, Inc., Phoenix.

2000 *Cultivated Landscapes of Native North America.* Oxford University Press, New York.

Doolittle, W. E., and C. Frederick
1991 Phytoliths as Indicators of Prehistoric Maize Cultivation. *Plant Systematics and Evolution* 177:175–184.

Doolittle, W. E., J. A. Neely, and M. D. Pool
1993 A Method for Distinguishing between Prehistoric and Recent Water and Soil Control Features. *Kiva* 59:7–26.

*This discussion on assessing and discerning the difference between prehistoric and historic/modern water control features is very useful. It also provides background discussions of feature integrity that can be used in assessing the integrity of features in terms of their National Register of Historic Places eligibility.

Douglas, J. E., and D. B. Craig
1986 *Investigations of Archaic and Hohokam Sites on the Flying V Ranch, Tucson, Arizona.* Archaeological Report No. 13. Pima Community College, Tucson.

Dove, D. E.
1970 *A Site Survey along the Lower Agua Fria River, Arizona. The Arizona Archaeologist* No. 5. Phoenix.

1977 A Site Survey along the Lower Agua Fria River, Arizona. *The Arizona Archaeologist* 5:1–36. Reprinted. Originally published 1970.

Downing, T. E., and M. Gibson
1974 *Irrigation's Impact on Society.* Anthropological Papers of the University of Arizona No. 26. Tucson.

*A somewhat dated, but nevertheless important, series of articles on the role of irrigation in the development of human society in a worldwide perspective.

Downum, C. E.
1986 The Occupational Use of Hill Space in the Tucson Basin: Evidence from Linda Vista Hill. *The Kiva* 51:219–232.

1992 The Sinagua. *Plateau* 63 (1).

1993 *Between Desert and River: Hohokam Settlement and Land Use in the Los Robles Community.* Anthropological Papers of the University of Arizona No. 57. Tucson.

Downum, C. E., and A. Sullivan
1990 Settlement Patterns. In *The Wupatki Archaeological Inventory Survey Project,* edited by B. Anderson. Professional Paper No. 35. USDI National Park Service, Southwest Cultural Resources Center, Santa Fe.

Doyel, D.
1978 Sand Dune Farming in the Upper Little Colorado, Arizona. Paper presented at the 1978 Ethnobiology Conference, Flagstaff. On file, Arizona State Museum, Tucson.

1980 Hohokam Social Organization and the Sedentary to Classic Transition. In *Current Issues in Hohokam Prehistory: Proceedings of a Symposium,* edited by D. E. Doyel and F. Plog, pp. 23–40. Anthropological Research Papers No. 23. Arizona State University, Tempe.

1981 Prehistoric Environment, Land Use, and Subsistence in Dead Valley, East-Central Arizona. *The Kiva* 46:143–154.

1984 Sedentary Period Hohokam Paleo-Economy in the New River Drainage, Central Arizona. In *Prehistoric Agricultural Strategies in the Southwest,* edited by S. K. Fish and P. R. Fish, pp. 34–52. Anthropological Research Paper No. 33. Arizona State University, Tempe.

1985 Prehistoric Agriculture and Water Control at the Antelope Glyph Site. In *Hohokam Settlement and Economic Systems in the Central New River Drainage, Arizona,* edited by D. E. Doyel and M. D. Elson, pp. 297–315. Publications in Archaeology No. 4. Soil Systems, Inc., Phoenix.

1991 Hohokam Cultural Evolution in the Phoenix Basin. In *Exploring the Hohokam: Prehistoric Desert Peoples of the American Southwest,* edited by G. J. Gumerman, pp. 231–278. University of New Mexico Press, Albuquerque.

1993a *Prehistoric Non-Irrigated Agriculture in Arizona: A Historic Context for Planning.* Estrella Cultural Research Paper No. 3. Phoenix. Prepared for Arizona State Historic Preservation Office.

1993b Interpreting Prehistoric Cultural Diversity in the Arizona Desert. In *Culture and Contact: Charles C. Di Peso and the Gran Chichimeca,* edited by A. Woosley and J. Ravesloot, pp. 39–64. University of New Mexico Press, Albuquerque.

1995 A Regional Perspective on the Late Classic Period in the Phoenix Basin. In *Archaeological Excavations at Pueblo Blanco: The MCDOT Alma School Road Project,* edited by D. E. Doyel, A. T. Black, and B. S. Macnider, pp. 483–495. Archaeological Resources Report No. 90, Vol. 2. Archaeological Consulting Services, Ltd., Tempe.

2001 Settlement Organization at Gila Bend. In *The Hohokam Village Revisited*, edited by D. E. Doyel, S. K. Fish, and P. R. Fish, pp. 101–138. Southwestern and Rocky Mountain Division of the American Association for the Advancement of Science, Fort Collins.

Doyel, D. E., J. S. Crary, G. Gage, and K. J. Jensen
1995 *A Class One Overview for the Proposed San Carlos Irrigation Project Joint Works Rehabilitation.* Archaeological Consulting Services, Ltd., Tempe.

Doyel, D., and S. Debowski (editors)
1980 *Prehistory in Dead Valley, East-Central Arizona: The TG&E Springerville Report.* Arizona State Museum Archaeological Series No. 144. Tucson.

Doyel, D., and M. Elson (editors)
1985 *Hohokam Settlement and Economic Systems in the Central New River Drainage, Arizona.* 2 vols. Publications in Archaeology No. 4. . Soil Systems, Inc., Phoenix.

Doyel, D. E., S. K. Fish, and D. H. Johnson
1993 Prehistoric Non-Irrigated Agriculture in Arizona. In *Prehistoric Non-Irrigated Agriculture in Arizona: A Historic Context for Planning,* by D. E. Doyel, pp. 6–29. Estrella Cultural Research Paper No. 3. Phoenix. Prepared for Arizona State Historic Preservation Office.

Doyel, D., and B. Macnider
1991 *Under the Mogollon Rim: Cultural Resource Overview of the Mogollon Rim Study Area, Tonto National Forest.* Cultural Resources Report No. 42. Archaeological Consulting Services, Ltd., Tempe.

Duering, W. E.
1973 An Archaeological Survey of the Eastwing Switching Station. Ms. on file, Arizona State Museum, Tucson.

Eighmy, J. L., and J. B. Howard
1991 Direct Dating of Prehistoric Canal Sediments Using Archaeomagnetism. *American Antiquity* 56:88–102.

Ellis, W.
1992 The Gift of Gardening. *National Geographic* 181:52–81.

Elson, M. D.
1996 A Revised Chronology and Phase Sequence for the Lower Tonto Basin of Central Arizona. *Kiva* 62:117–147.

Elson, M. D., and W. H. Doelle
1987 *Archaeological Survey in Catalina State Park with a Focus on the Romero Ruin.* Technical Report No. 87-4. Institute for American Research, Tucson.

Elson, M. D., and D. A. Gregory
1995 Tonto Basin Chronology and Phase Sequence. In *The Roosevelt Community Development Study: New Perspectives on Tonto Basin Prehistory,* edited by M. D. Elson, M. T. Stark, and D. A. Gregory, pp. 61–77. Anthropological Papers No. 15. Center for Desert Archaeology, Tucson.

Elson, M. D., D. A. Gregory, and M. T. Stark
1995 New Perspectives on Tonto Basin Prehistory. In *The Roosevelt Community Development Study: New Perspectives on Tonto Basin Prehistory,* edited by M. D. Elson, M. T. Stark, and D. A. Gregory, pp. 441–479. Anthropological Papers No. 15. Center for Desert Archaeology, Tucson.

Elson, M. D., and M. Lindeman
1994 The Eagle Ridge Site, AZ V:5:104/1045(ASM/TNF). In *The Roosevelt Community Development Study: Introduction and Small Sites*, by M. D. Elson and D. L. Swartz, pp. 23–116. Anthropological Papers No. 13, Vol. 1. Center for Desert Archaeology, Tucson.

Ely, L., Y. Enzel, V. R. Baker, and D. Cayan
1993 A 5,000 Year Record of Extreme Floods and Climate Change in the Southwestern United States. *Science* 262:410–412.

Euler, R. C.
1958 *Walapai Culture History.* Unpublished Ph.D. dissertation, Department of Anthropology, University of New Mexico, Albuquerque.

1982 Ceramic Patterns of the Hakataya Tradition. In *Southwestern Ceramics: A Comparative Review,* edited by A. H. Schroeder, pp. 53–70. *The Arizona Archaeologist* No. 15. Arizona Archaeological Society, Phoenix.

Euler, R. C., and D. F. Green
1978 *An Archeological Reconnaissance of Middle Havasu Canyon, Arizona.* Cultural Resources Report No. 22. USDA Forest Service, Southwestern Region, Albuquerque.

Evans, G. L.
1951 Prehistoric Wells in Eastern New Mexico. *American Antiquity* 17:1–9.

Evenari, M., L. Shanan, and N. Tadmor
1982 *The Negev: The Challenge of the Desert.* Harvard University Press, Cambridge.

Ezell, P. H.
1961 *The Hispanic Acculturation of the Gila River Pimas.* Memoir No. 90. American Anthropological Association, Washington, D.C.

1963 Is There a Hohokam-Pima Cultural Continuum? *American Antiquity* 29:61–66.

Ezzo, J. A., and W. L. Deaver
1998 *Watering the Desert: Late Archaic Farming at the Costello-King Site.* Technical Series No. 68. Statistical Research, Inc., Tucson.

Farrington, I., and C. C. Park
1978 Hydraulic Engineering and Irrigation Agriculture in the Moche Valley, Peru, ca. A.D. 1250–1532. *Journal ofArchaeological Science* 5:255–268.

Ferg, A.
1986 Hohokam T-shaped stones. Paper presented at the Second Tucson Basin Conference, Tucson.

Ferguson, T. J., and E. R. Hart
1985 *A Zuni Atlas*. University of Oklahoma Press, Norman.

Fewkes, J. W.
1898 Archeological Expedition to Arizona in 1895. *Seventeenth Annual Report of the Bureau of Ethnology to the Secretary of the Smithsonian Institution 1895-'96,* by J. W. Powell, pp. 719–742. U.S. Government Printing Office, Washington, D.C.

1904 *Two Summers' Work in Pueblo Ruins.* Twenty-Second Annual Report of the Bureau of American Ethnology 1900–1901. Smithsonian Institution, Washington, D.C.

Fink, T. M.
1991 The Prehistoric Irrigation Canals and Reservoirs of Southern Arizona and Their Possible Impact on Hohokam Health. In *Prehistoric Irrigation in Arizona: Symposium 1988,* edited by C. D. Breternitz, pp. 61–87. Publications in Archaeology No. 17. Soil Systems, Inc., Phoenix.

Fish, P. R.
1968 Gila Dunes: A Chiricahua Stage Site near Florence, Arizona. Ms. on file (AZ U:15:8[ASU]), Department of Anthropology, Arizona State University, Tempe.

1989 The Hohokam: 1,000 Years of Prehistory in the Sonoran Desert. In *Dynamics of Southwest Prehistory,* edited by L. S. Cordell and G. J. Gumerman. School of American Research Advanced Seminar Book. Smithsonian Institution Press, Washington, D.C.

Fish, P. R., and S. K. Fish
1977 *Verde Valley Archaeology: Review and Perspective.* Research Paper No. 8. Museum of Northern Arizona, Flagstaff.

1984 Agricultural Maximization in the Sacred Mountain Basin. In *Prehistoric Agricultural Strategies in the Southwest,* edited by S. K. Fish and P. R. Fish, pp. 147–159. Anthropological Research Papers No. 33. Arizona State University, Tempe.

1991 Hohokam Political and Social Organization. In *Exploring the Hohokam: Prehistoric Desert Peoples of the American Southwest*, edited by G. J. Gumerman, pp. 151–175. Amerind Foundation New World Studies Series No. 1. University of New Mexico Press, Albuquerque.

Fish, P. R., S. K. Fish, and G. J. Gumerman
1994 Toward an Explanation for Southwestern "Abandonments." In *Themes in Southwestern Prehistory*, edited by G. J. Gumerman, pp. 135–165. School of American Research Press, Santa Fe.

Fish, P. R., S. K. Fish, A. Long, and C. Miksicek
1986 Early Corn Remains from Tumamoc Hill, Southern Arizona. *American Antiquity* 51:567–572.

Fish, P. R., S. K. Fish, and J. H. Madsen
1985 A Preliminary Analysis of Hohokam Settlement and Agriculture in the Northern Tucson Basin. In *Proceedings of the 1983 Hohokam Symposium, Part I*, edited by A. E. Dittert, Jr., and D. E. Dove, pp. 75–100. Occasional Paper No. 2. Arizona Archaeological Society, Phoenix.

1989 Prehistoric Community Integration in the Tucson Basin. In *The Political Structure of Prehistoric Southwestern Societies,* edited by S. Upham and K. G. Lightfoot. Westview Press, Denver. In press.

Fish, P. R., P. S. Pilles, Jr., and S. K. Fish
1980 Colonies, Traders and Traits: The Hohokam in the North. In *Current Issues in Hohokam Prehistory,* edited by D. E. Doyel and F. Plog, pp. 151–175. Anthropological Research Papers No. 23. Arizona State University, Tempe.

Fish, S. K.
1983 Pollen from Agricultural Features. In *Hohokam Archaeology along the Salt-Gila Aqueduct, Central Arizona Project: Specialized Activity Sites*, edited by L. S. Teague and P. L. Crown, pp. 575–603. Archaeological Series No. 150, Vol. 3. Arizona State Museum, University of Arizona, Tucson.

1984 Agriculture and Subsistence Implications of the Salt-Gila Aqueduct Project Pollen Analysis. In *Hohokam Archaeology along the Salt-Gila Aqueduct,* edited by L. S. Teague and P. L. Crown, pp. 111–137. Arizona State Museum Archaeological Series No. 150, Vol. 7. Tucson.

1995 Mixed Agricultural Technologies m Southern Arizona and Their Implications. In *Soil, Water, Biology, and Belief in Prehistoric and Traditional Southwestern Agriculture,* edited by H. W. Toll, pp. 101–116. New Mexico Archaeological Council, Albuquerque.

Fish, S. K., and M. Donaldson
1991 Production and Consumption m the Archaeological Record: A Hohokam Example. *Kiva* 56:255275.

2000 Unsuspected Magnitudes: Expanding the Scale of Hohokam Agriculture. In *Human Impact on the Environment. An Archaeological Perspective,* edited by C. Redman, S. James, P. R. Fish, and J. Rogers. Smithsonian Institution Press, Washington D.C. (in press)

Fish, S. K., and P. R. Fish (editors)
1984 *Prehistoric Agricultural Strategies in the Southwest.* Anthropological Research Paper No. 33. Arizona State University, Tempe.

*Many of the articles in this volume focus on aspects of Arizona archaeology. Topics also include agricultural technologies and the sociopolitical implications of agriculture.

Fish, S. K., P. R. Fish, and C. Downum
1984 Hohokam Terraces and Agricultural Production m the Tucson Basin. In *Prehistoric Agricultural Strategies in the Southwest,* edited by S. K. Fish and P. R. Fish, pp. 55–71. Anthropological Research Paper No. 33. Arizona State University, Tempe.

Fish, S. K., P. R. Fish, and J. H. Madsen
1990 Sedentism and Settlement Mobility m the Tucson Basin Prior to A.D. 1000. In *Perspectives on Southwestern Prehistory,* edited by P. Minnis and C. Redman, pp. 76–91. Westview Press, Boulder.

1992 Evidence for Large-scale Agave Cultivation in the Marana Community. In The *Marana Community in the Hohokam World,* edited by S. K. Fish, P. R. Fish, and J. H. Madsen, pp. 73–87. Anthropological Papers of the University of Arizona No. 56. University of Arizona Press, Tucson.

Fish, S. K., P. R. Fish, and J. H. Madsen (editors)
1992 *The Marana Community in the Hohokam World.* Anthropological Papers of the University of Arizona No. 56. University of Arizona Press, Tucson.

*This volume is a primary source of information on non-irrigation agriculture and the use of agave in the southern Hohokam area.

Fish, S. K., P. R. Fish, C. Miksicek, and J. H. Madsen
1985 Prehistoric Agave Cultivation in Southern Arizona. *Desert Plants* 7:107–112.

Fish, S. K., and G. Nabhan
1991 Desert as Context: The Hohokam Environment. In *Exploring the Hohokam Prehistoric Desert People of the American Southwest,* edited by G. Gumerman, pp 29–60. University of New Mexico Press, Albuquerque.

Fish, S., and K. Reichhardt

1983 Summary of Landsurface Feature Mapping of BLM Mitigation Site, Apache Junction Unified School District. Ms. on file, Applied Remote Sensing Center, Office of Arid Lands Studies, University of Arizona, Tucson.

Ford, R. I.

1981 Gardening and Farming before A.D. 1000: Patterns of Prehistoric Cultivation North of Mexico. *Journal of Ethnobiology* 1:6–27.

1985 The Processes of Plant Food Production in Prehistoric North America. In *Prehistoric Food Production in North America,* edited by R. I. Ford, pp. 1–18. Museum of Anthropology Anthropological Papers No. 75. University of Michigan, Ann Arbor.

Forde, C. D.

1931 Hopi Agriculture and Land Ownership. *Journal of the Royal Anthropological Institute of Great Britain and Ireland* 61:357–407.

Foster, M. S.

1991 The Early Ceramic Period in Northwest Mexico: An Overview. In *Mogollon V*, edited by P. H. Beckett, pp. 155–165. COAS Publishing and Research, Las Cruces.

1995 The Loma San Gabriel Culture and its Suggested Relationships to other Early Plainware Cultures of Northwest Mesoamerica. In *The Gran Chichimeca: Essays on the Archaeology and Ethnohistory of Northern Mesoamerica,* edited by J. E. Reyman, pp. 179–207. Avebury Press, U.K.

2000 *A Cultural Resources Testing Program at 32 Proposed Home Sites on the Gila River Indian Community, Maricopa and Pinal Counties, Arizona.* CRMP Technical Report No. 2000–02. Cultural Resource Management Program, Gila River Indian Community, Sacaton.

Fowler, A., and J. Stein

1992 The Anasazi Great House in Space, Time and Paradigm. In *Anasazi Regional Organization and the Chaco System,* edited by D. Doyel, pp. 101–122. Maxwell Museum Papers in Anthropology No. 5. Albuquerque.

Freeman, A. K.

1995 Reading the Stories of Ancient Canals. *Archaeology in Tucson* 9:7.

French, R. H.

1985 *Open-Channel Hydraulics.* McGraw-Hill, New York.

Frick, P.

1954 *An Archaeological Survey in the Central Santa Cruz Valley, Southern Arizona.* Unpublished Master's thesis, Department of Anthropology, University of Arizona, Tucson

Fuller, S., A. Rogge, and L. Gregonis

1976 *Orme Alternatives: The Archaeological Resources of Roosevelt Lake and Horseshoe Reservoir.* Arizona State Museum Archaeological Series No. 98. Tucson.

Gardiner, R., W. B. Masse, and C. D. Halbirt

1987 Data Recovery at AZ U:9:71(ASM). In *Archaeological Investigations of Portions of the Las Acequias–Los Muertos Irrigation System: Testing and Partial Data Recovery within the Tempe Section of the Outer Loop Freeway System, Maricopa County, Arizona,* edited by W. Bruce Masse, pp. 25–56. Archaeological Series No. 176. Arizona State Museum, University of Arizona, Tucson.

Gasser, R., and S. Kwiatkowski

1991 Food for Thought: Recognizing Patterns in Hohokam Subsistence. In *Exploring the Hohokam: Prehistoric Desert Dwellers of the American Southwest,* edited by G. Gumerman, pp. 4 17–460. University of New Mexico Press, Albuquerque.

*This article is a useful and comprehensive summary of Hohokam subsistence patterns.

Gasser, R., and S. Kwiatkowski (editors)

1991 Hohokam Ethnobotany. *Kiva* 56.

Gasser, R., C. Robinson, and C. Breternitz (editors)

1990 *Archaeology of the Ak-chin Indian Community West Side Farms Project: The Land and the People.* Soil Systems Publications in Archaeology No. 9. Phoenix.

Gasser, R. E., D. E. Weaver, and J. S. Bruder

1984 *Definitions of the Boundaries for the Midvale Site, Williams Air Force Base.* Museum of Northern Arizona, Department of Anthropology, Flagstaff.

Geib, P. R., and B. B. Huckell

1994 Evidence of Late Preceramic Agriculture at Cibeque, East-Central Arizona. *Kiva* 59:433–454.

Gilbertson, D. D.

1986 Runoff (Floodwater) Farming and Rural Water Supply in Arid Lands. *Applied Geography* 6:5–11.

Gilman, P. A.

1991 Changing Land Use and Pit Structure Seasonality along the San Simon Drainage in Southeastern Arizona. In *Mogollon V,* edited by P. H. Becket, pp. 11–27. COAS Publishing and Research, Las Cruces.

1997 *Wandering Villagers: Pit Structures, Mobility, and Agriculture in Southeastern Arizona.* Anthropological Research Papers No. 49. Arizona State University, Tempe.

Gish, J. W.

1989 A Pollen Evaluation of the Las Acequias Canal System. In *Prehistoric Agricultural Activities on the Lehi-Mesa Terrace: Perspectives on Hohokam Irrigation Cycles*, edited by N. W. Ackerly and T. K. Henderson, pp. 279–332. Northland Research, Inc., Flagstaff

1991 Current Perceptions, Recent Discoveries, and Future Directions in Hohokam Palynology. *Kiva* 56:237–254.

Gladwin, H. S., E. W. Haury, E. B. Sayles, and N. Gladwin

1937 *Excavations at Snaketown: Material Culture.* Medallion Papers No. 25. Gila Pueblo, Globe, Arizona.

Glassow, M. A.

1980 *Prehistoric Agricultural Development in the Northern Southwest: A Study in Changing Patterns of Land Use.* Ballena Press, Socorro, New Mexico.

*Glassow describes and discusses a variety of water-management techniques used and suggested to have been used in the prehistoric Southwest. Although the volume is somewhat dated, it does provide a useful survey on this topic.

Goodyear, A. C., III

1975 *Hecla II and III: An Interpretive Study of Archaeological Remains from the Lakeshore Project, Papago Indian Reservation, South-central Arizona.* Anthropological Research Papers No. 4. Arizona State University, Tempe.

Graf, W. L.
1988 *Fluvial Processes in Dryland Rivers.* Springer-Verlag, New York.

Granger, B. H.
1983 *Arizona's Names (X Marks the Place).* Treasure Chest Publications, Tucson.

Graybill, D.
1989 The Reconstruction of Prehistoric Salt River Streamflow. In *The 1982–84 Excavations at Las Colinas: Environment and Subsistence,* by D. A. Graybill, D. A. Gregory, F. L. Nials, S. K. Fish, R. E. Gasser, C. H. Miksicek, and C. R. Szuter, pp. 25–38. Arizona State Museum Archaeological Series No. 162, Vol. 5. Tucson.

*A seminal study of prehistoric Salt River and Verde River streamflow.

1999 Long-Term Streamflow Reconstructions, River Channel Morphology, and Aboriginal Irrigation Systems along the Salt and Gila Rivers. In *Environmental Change and Human Adaptation in the Ancient Southwest,* edited by J. S. Dean and D. E. Doyel. University of Utah Press. In preparation.

Green, M.
1989 *Settlement, Subsistence, and Specialization in the Northern Periphery: The Waddell Project.* Cultural Resources Report No. 65. Archaeological Consulting Services, Ltd., Tempe.

1990 *Hohokam Utilization of the Intermontane Mazatzal Region: The State Route 87 Pine Creek Project, Mesa Ranger District, Tonto National Forest, Arizona.* Cultural Resources Report No. 66. Archaeological Consulting Services, Ltd., Tempe.

Greenwald, D. H., K. C. Anderson, S. Kwiatkowski, and L. S. Cummings
1996 Agricultural Fields: Geomorphic, Chemical, Botanical, and Archaeological Evidence. In *The Sky Harbor Project, Early Desert Farming and Irrigation Settlements: Archaeological Investigations in the Phoenix Sky Harbor Center, Special Studies, Synthesis, and Conclusions,* edited by D. H. Greenwald and J. H. Ballagh, pp. 49–75. SWCA Anthropological Research Paper No. 4, Vol. 4. Flagstaff and Tucson.

Greenwald, D. H., and R. Ciolek-Torrello
1988 *Archaeological Investigations at the Dutch Canal Ruin, Phoenix, Arizona: Archaeology and History along the Papago Freeway Corridor.* Research Paper No. 38. Museum of Northern Arizona, Flagstaff.

Gregory, D. A.
1987 The Morphology of Platform Mounds and the Structure of Classic Period Hohokam Sites. In *The Hohokam Village: Site Structure and Organization,* edited by D. E. Doyel, pp. 183–210. American Association for the Advancement of Science, Glenwood Springs, Colorado.

1991 Form and Variation in Hohokam Settlement Patterns. In *Chaco and Hohokam: Prehistoric Regional Systems in the American Southwest,* edited by P. L. Crown and W. J. Judge, pp. 159–193. School of American Research Press, Santa Fe.

1995 A Chronological Framework for the Prehistory of the Safford Basin. In *The San Carlos Reservoir Cultural Resources Survey,* edited by A. T. Black and M. Green, pp. 123–136. Cultural Resources Report No. 87, Vol. 1. Archaeological Consulting Services, Ltd., Tempe.

1999 Data Integration and Synthesis. In *Excavations in the Santa Cruz River Floodplain: The Middle Archaic Component at Los Pozos,* edited by D. A. Gregory, pp. 85–123. Anthropological Papers No. 20. Center for Desert Archaeology, Tucson.

2001 Extramural Features. In *Excavations in the Santa Cruz River Floodplain: The Early Agricultural Period Component at Los Pozos*, edited by D. A. Gregory, pp. 71–90. Anthropological Papers No. 21. Center for Desert Archaeology, Tucson.

Gregory, D. A., and G. Huckleberry

1994 *An Archaeological Survey of the Blackwater Area: The History of Human Settlement in the Blackwater Area.* Cultural Resources Report No. 86, Vol. 1. Archaeological Consulting Services, Ltd., Tempe.

Gregory, D. A., and F. Nials

1985 Observations Concerning the Distribution of Classic Period Hohokam Platform Mounds. In *Proceedings of the 1983 Hohokam Conference*, edited by A. E. Dittert and D. E. Dove, pp. 373–388. Occasional Paper No. 2. Arizona Archaeological Society, Phoenix.

Gumerman, G. J. (editor)

1991 *Exploring the Hohokam: Prehistoric Desert People of the American Southwest.* University of New Mexico Press, Albuquerque.

Gumerman, G. J., and J. S. Dean

1989 Prehistoric Cooperation and Competition in the Western Anasazi Area. In *Dynamics of Southwestern Prehistory,* edited by L. S. Cordell and G. J. Gumerman, pp. 99–148. Advanced Seminar Book, School of American Research, Santa Fe. Smithsonian Institution Press, Washington, D.C., and London.

Hack, J.

1942 *The Changing Physical Environment of the Hopi Indians of Arizona.* Papers of the Peabody Museum of Archaeology and Ethnology No. 35, Vol. 1. Harvard University, Cambridge.

*Classic study of Hopi agriculture. Many of the methods used historically and today by the Hopi are analogs for prehistoric agriculture and water management in Arizona.

Hackbarth, M. R.

1992 *Prehistoric and Historic Occupation of the Lower Verde River Valley: The State Route 87 Verde Bridge Project.* Northland Research, Inc., Flagstaff.

Hackbarth, M. R., T. D. Henderson, and D. B. Craig

1995 *Archaeology at the Head of the Scottsdale Canal System: Canal and Synthetic Studies.* Anthropological Papers No. 95-1, Vol. 3. Northland Research, Inc., Flagstaff.

Hackenberg, R. A.

1974 Aboriginal Land Use and Occupancy of the Papago Indians. In *Papago Indians I. American Indian Ethnohistory: Indians of the Southwest,* edited by D. A. Horr, pp. 23–308. Garland, New York.

1983 Pima and Papago Ecological Adaptations. In *Southwest,* edited by A, Ortiz, pp. 161–177. Handbook of North American Indians, vol. 10, W. C. Sturtevant, general editor. Smithsonian Institution, Washington, D.C.

Hagenstad, B.

1969 A Glance at the History and Archaeology of the Lower Verde River. *The Arizona Archaeologist* 4:24–32. Arizona Archaeological Society, Phoenix.

Halbirt, C. D., and T. K. Henderson (editors)

1993 *Archaic Occupation on the Santa Cruz Flats: The Tator Hills Archaeological Project.* Northland Research, Inc., Flagstaff.

Halseth, O. S.

1932 Prehistoric Irrigation in Central Arizona. *The Masterkey* 5:165–175.

Hammack, L. C.

1971 The Peppersauce Wash Project: A Preliminary Report on the Salvage Excavation of Four Archaeological Sites in the San Pedro Valley, Southeastern Arizona. Arizona Highway Salvage. Ms. on file, Arizona State Museum, University of Arizona, Tucson.

Hard, R. J.

1988 Agricultural Dependence in the Mountain Mogollon. In *Perspectives on Southwestern Prehistory,* edited by P. Minnis and C. Redman, pp. 239–257. Westview Press, Boulder.

Hard, R. J., R. P. Mauldin, and G. R. Raymond

1996 Mano Size, Stable Carbon Isotope Ratios, and Macrobotanical Remains as Multiple Lines of Evidence of Maize Dependency in the American Southwest. *Journal of Archaeological Method and Theory* 3:253–318.

Hard, R. J., and J. R. Roney

1998 A Massive Terraced Village Complex in Chihuahua, Mexico, 3000 Years Before Present. *Science* 279:1661–1664.

Hartman, D.

1976 *Tuzigoot: An Archeological Overview.* Research Paper No. 4, Anthropology Research Report No. 4. Museum of Northern Arizona. Flagstaff.

Hartmann, G. H., and M. C. Thurtle

2001 The Archaeology of Tinajas Altas, a Desert Water Hole in Southwestern Arizona. *Kiva* 66:489–518.

Haury, E. W.

1932 *Roosevelt 9:6, a Hohokam Site of the Colonial Period.* Medallion Papers No. 11. Gila Pueblo, Globe, Arizona.

1936 Vandal Cave. *The Kiva* 1:1–4.

1937 The Snaketown Canal. In *Excavations at Snaketown: Material Culture*, edited by H. S. Gladwin, E. W. Haury, E. B. Sayles, and N. Gladwin, pp. 50–58. Medallion Papers No. 25. Gila Pueblo, Globe, Arizona.

1940 *Excavations in the Forestdale Valley, East-Central Arizona.* University of Arizona Press, Tucson.

1945 *The Excavation of Los Muertos and Neighboring Ruins in the Salt River Valley, Southern Arizona.* Papers of the Peabody Museum of American Archaeology and Ethnology No. 24, Vol. 1. Harvard University, Cambridge.

1950 *The Stratigraphy and Archaeology of Ventana Cave.* University of Arizona Press, Tucson.

1957 An Alluvial Site on the San Carlos Indian Reservation, Arizona. *American Antiquity* 23:2–27.

1962 The Greater American Southwest. In *Courses toward Urban Life,* edited by R. Braidwood and G. Willey, pp. 106–131. Viking Fund Publications in Anthropology No. 32. New York.

1976 *The Hohokam, Desert Farmers and Craftsmen: Excavations at Snaketown 1964–1965.* University of Arizona Press, Tucson.

1984 The Search for Chichilticale. *Arizona Highways* 60:14–19.

Haury, E. W., and L. L. Hargrave

1931 Recently Dated Pueblo Ruins in Arizona. Smithsonian Miscellaneous Collections Vol. 82, No. 11. Smithsonian Institution, Washington, D.C.

Hayden, J. D.
1967 A Summary Prehistory and History of the Sierra Pinacate, Sonora, Mexico. *American Antiquity* 41:274–289.

1972 Hohokam Petroglyphs of the Sierra Pinacate, Sonora, and the Hohokam Shell Expeditions. *The Kiva* 37:74–84.

1976 Pre-altithermal Archaeology in the Sierra Pinacate, Sonora, Mexico. *American Antiquity* 41: 274–289.

1987 The Vikita Ceremony of the Papago. *Journal of the Southwest* 29:273–324.

Haynes, C. V., Jr.
1973 Exploration of a Mammoth-Kill Site in Arizona. *National Geographic Society Research Reports, 1966,* pp. 125–126. Washington, D.C.

1980 The Clovis Culture. *Canadian Journal of Anthropology* 1:115–121.

Heidke, J. M.
1999 Cienega Phase Incipient Plain Ware from Southeastern Arizona. *Kiva* 64:311–338.

Henderson, T. K.
1989 *Prehistoric Agricultural Activities on the Lehi-Mesa Terrace: Excavations at La Cuenca del Sedimento.* Northland Research, Inc., Flagstaff.

Henderson, T. K., and M. R. Hackbarth
2000 What is Going On at the Hohokam Village? A Fourteenth and Fifteenth Century Perspective. In *The Hohokam Village Revisited,* edited by D. E. Doyel, S. K. Fish, and P. R. Fish, pp. 287–316. Southwestern and Rocky Mountain Division of the American Association for the Advancement of Science, Fort Collins.

Henders
1979 *Archaeological Investigations in the Cave Creek Area, Maricopa County, South-Central Arizona.* Arizona State University Anthropological Research Papers No. 17. Arizona State University, Tempe.

Herskov
1981 Arizona U:9:46, a Dual Component Hohokam Site in Tempe, Arizona. *The Kiva* 47:1–90.

Hester, T. R., and R. F. Heizer
1972 Problems in the Functional Interpretation of Artifacts: Scraper Planes from Mitla and Yagul, Oaxaca. *University of California Archaeological Facility Papers* 14:109–110. Department of Anthropology, University of California, Los Angeles.

Heuett, M. L.
2000 *Archaeological Investigations at the Headwaters of Cañada del Oro Creek on the Golder Ranch Property in Southeastern Pinal County, Arizona.* Southwest Cultural Series No. 30. Cultural and Environmental Systems, Inc., Tucson.

Hewitt, J. M., and D. Stephen
1981 *Archaeological Investigations in the Tortolita Mountains Region, Southern Arizona.* Archaeological Field Report No. 10. Pima Community College, Tucson.

Hillel, D.
1991 *Out of the Earth: Civilization and the Life of the Soil.* Free Press, New York.

Hodge, F. W.
1893 Prehistoric Irrigation in Arizona. *American Anthropologist* 6:323–330.

*Classic early reference.

Hodgson, W., G. Nabhan, and L. Ecker
1989 Prehistoric Fields in Arizona: Conserving Rediscovered Agave Cultivars. *Agave* 3:9–11.

Hohmann, J. W.
1983 *Sinagua Social Differentiation: Inferences Based on Prehistoric Mortuary Practices. The Arizona Archaeologist* No. 17. Arizona Archaeological Society, Phoenix.

Holiday, W. G.
1974 *Archaeological Investigations in the Cave Creek Drainage, Tonto National Forest, Arizona.* Archeological Report No. 1. USDA Forest Service, Southwestern Region, Albuquerque.

Holmlund, J. P.
1986 Earthquake Activity. In *Petroglyphs of the Picacho Mountains, South Central Arizona,* by H. D. Wallace and J. P. Holmlund, pp. 163–170. Anthropological Papers No. 6. Institute for American Research, Tucson.

Homburg, J. A.
1997 Prehistoric Dryland Agricultural Fields of the Lower Verde Valley. In *Vanishing River, The Lower Verde Valley Project, Vol. 2: Agriculture, Subsistence, and Environmental Studies*, edited by S. M. Whittlesy, R. Ciolek-Torrello, and J. H. Altschul, pp. 103–126. SRI Press, Tucson.

Hough, W.
1907 *Antiquities of the Upper Gila and Salt River Valleys in Arizona and New Mexico.* Bureau of American Ethnology Bulletin No. 35. U.S. Government Printing Office, Washington, D.C.

House, K., R. H. Webb, V. R. Baker, and D. R. Levish
2002 *Ancient Floods, Modern Hazards: Principles and Applications of Paleoflood Hydrology.* Water Science and Application Vol. 5. American Geophysical Union, Washington, D.C.

Howard, J. B.
1985 Courtyard Groups and Domestic Cycling: A Hypothetical Model of Growth. In *Proceedings of the 1983 Hohokam Symposium,* edited by A. E. Dittert, Jr., and D. E. Dove, pp. 311–326. Occasional Paper No. 2, Pt. 1. Arizona Archaeological Society, Phoenix.

1987 The Lehi Canal System: Organization of a Classic Period Community. In *The Hohokam Village: Site Structure and Organization,* edited by D. E. Doyel, pp. 211–221. American Association for the Advancement of Science, Glenwood Springs, Colorado.

1988a Canal Systems, Labor Investments and Sociopolitical Organization. Paper presented at the Arizona Archaeological Council "Prehistoric Irrigation in Arizona" symposium, Phoenix.

1988b The Casa Buena Canals. In *Excavations at Casa Buena: Changing Hohokam Land Use along the Squaw Peak Parkway,* edited by J. B. Howard, pp. 245–269. Publications in Archaeology No. 11. Soil Systems, Inc., Phoenix.

1990 *Paleohydraulics: Techniques for Modeling the Operation and Growth of Prehistoric Canal Systems.* Unpublished Master's thesis, Department of Anthropology, Arizona State University, Tempe.

*This is a basic reference in the study of the functioning of Hohokam canals. Howard studies canal morphology and paleohydraulics to determine the capacity of canal systems. Labor investment, calculations of acres irrigated, and a model of the evolution of an irrigation community are included.

1991 Regression Modeling of Canal Morphology and Paleohydraulics. In *The Operation and Evolution of an Irrigation System: The East Papago Canal Study,* by J. Howard and G. Huckleberry, pp. 4.1–38. Publications in Archaeology No. 18. Soil Systems, Inc., Phoenix.

1993 A Paleohydraulic Approach to Examining Agricultural Intensification in Hohokam Irrigation Systems. In *Research in Economic Anthropology, Supplement 7,* pp. 263–324. JAI Press, Greenwich.

1994 A Paleohydraulic Approach to Examining Agricultural Intensification in Hohokam Irrigation Systems. In *Research in Economic Anthropology, Supplement 7*, pp. 261–322. JAI Press, Greenwich.

Howard, J. B., and G. Huckleberry

1988 Canal Studies in the New Alignment of the Hohokam Expressway, Phoenix, Arizona. Paper presented at the Arizona Archaeological Council "Prehistoric Irrigation in Arizona" symposium, Phoenix.

1991 *The Operation and Evolution of an Irrigation System: The East Papago Canal Study.* Publications in Archaeology No. 18. Soil Systems, Inc., Phoenix.

Howard, J. B., and G. Rice

1982 *The Archaeological Monitoring of Reach 1, Roosevelt Water Conservation District Floodway, Pinal County, Arizona.* OCRM Report No. 59. Office of Cultural Resource Management, Department of Anthropology, Arizona State University, Tempe.

Huckell, B. B.

1978 *The Oxbow Hill–Payson Project: Archaeological Excavations South of Payson, Arizona.* Arizona State Museum Contributions to Highway Salvage Archaeology in Arizona. University of Arizona, Tucson.

1982 *The Distribution of Fluted Points in Arizona: A Review and an Update.* Archaeological Series No. 145. Arizona State Museum, University of Arizona, Tucson.

1984a *The Archaic Occupation of the Rosemont Area, Northern Santa Rita Mountains, Southeastern Arizona.* Archaeological Series No. 147, Vol. 1. Arizona State Museum, University of Arizona, Tucson.

1984b The Paleo-Indian and Archaic Occupation of the Tucson Basin: An Overview. *The Kiva* 49:133–146.

1988 Late Archaic Archaeology of the Tucson Basin: A Status Report. In *Recent Research on Tucson Basin Prehistory: Proceedings of the Second Tucson Basin Conference,* edited by W. H. Doelle and P. R. Fish, pp. 57–80. Anthropological Papers No. 10. Institute for American Research, Tucson.

1990 Late Preceramic Farmer-Foragers in Southeastern Arizona. Unpublished Ph.D. dissertation, Office of Arid Lands Studies, University of Arizona, Tucson.

1995 Of *Marshes and Maize: Preceramic Agricultural Settlements in the Cienega Valley, Southeastern Arizona.* Anthropological Papers of the University of Arizona No. 59. University of Arizona Press, Tucson.

1996a The Archaic Prehistory of the North American Southwest. *Journal of World Prehistory* 10:305373.

1996b The Southwestern Archaic: Scale and Perception of Preceramic Hunter-Gatherers. In *Interpreting Southwestern Diversity: Underlying Principles and Overarching Patterns,* edited by P. R. Fish and J. J. Reid, pp. 7–15. Anthropological Research Papers No. 48. Arizona State Museum, Tucson.

Huckell, B. B., L. W. Huckell, and M. S. Shackley

1999 McEuen Cave. *Archaeology Southwest* 13:12. Center for Desert Archaeology, Tucson.

Huckell, B. B., M. D. Tagg, and L. W. Huckell

1987 *The Corona de Tucson Project: Prehistoric Use of a Bajada Environment.* Archaeological Series No. 174. Arizona State Museum, University of Arizona, Tucson.

Huckell, L. W.
1980 *An Archaeological Assessment of the Proposed Catalina State Park.* Archaeological Series No. 141. Arizona State Museum, University of Arizona, Tucson.

Huckleberry, G.
1987 Geoarchaeology of the Las Acequias–Los Muertos Canal System and the Peterson Ditch. In *Archaeological Investigations of Portions of the Las Acequias–Los Muertos Irrigation System: Testing and Partial Data Recovery within the Tempe Section of the Outer Loop Freeway System, Maricopa County, Arizona,* edited by W. B. Masse, pp. 139–157. Archaeological Series No. 176. Arizona State Museum, University of Arizona, Tucson.

1988a Reconstructing Hohokam Canal Hydrodynamics. Paper presented at the Arizona Archaeological Council "Prehistoric Irrigation in Arizona" symposium, Phoenix.

1988b Relict Irrigation Canals in the East Papago Freeway Corridor. In *Arizona Department of Transportation Archaeological Testing Program: East Papago Freeway,* edited by D. O. Landis, pp. 109–167. Publications in Archaeology No. 13, Pt. 2. Soil Systems, Inc., Phoenix.

1991
The East Papago Canal Study, by J. B. Howard and G. Huckleberry, pp. 31–75. Publications in Archaeology No. 18. Soil Systems, Inc., Phoenix.

1992 Soil Evidence of Hohokam Irrigation in the Salt River Valley, Arizona. *Kiva* 57:237–249.

1995a Canal Hydraulics, Sedimentology, and Structure in the Upper Reaches of the Scottsdale Canal System. In *Archaeology at the Head of the Scottsdale Canal System: Canal and Synthetic Studies*, edited by M. R. Hackbarth, T. D. Henderson, and D. B. Craig, pp. 49–65. Anthropological Papers No. 95-1, Vol. 3. Northland Research, Inc., Flagstaff.

1995b Archaeological Implications of Late-Holocene Channel Changes on the Middle Gila River, Arizona. *Geoarchaeology: An International Journal* 10:159–182.

1999a Assessing Hohokam Canal Stability through Stratigraphy. *Journal of Field Archaeology* 26:118.

1999b Stratigraphic Identification of Destructive Floods in Relict Canals: A Case Study from the Middle Gila River. *Kiva* 65:7–33.

1999c Prehistoric Flooding and Its Effect on Indigenous Agriculture in the Northern Sonoran Desert, U.S.A. *Journal of Arid Land Studies* 9:277–284.

Hunt, E., and R. C. Hunt
1974 Irrigation, Conflict, and Politics. In *Irrigation's Impact on Society,* edited by T. E. Downing and M. Gibson, pp. 129–157. Anthropological Papers of the University of Arizona No. 26. University of Arizona Press, Tucson.

Irwin-Williams, C., A. Dansie, J. O. Davis, and R. Jacobsen
1986 Prehistoric Water Harvesting Techniques in the Northern Great Basin. Paper presented at the 20th Biennial Great Basin Anthropological Conference, Las Vegas.

Jacobs, D.
1994 *Archaeology of the Salado in the Livingston Area of Tonto Basin, Roosevelt Platform Mound Study: Report on the Livingston Management Group, Pinto Creek Complex.* Roosevelt Monograph Series No. 3, Anthropological Field Studies No. 32. Office of Cultural Resource Management, Department of Anthropology, Arizona State University, Tempe

Jennings, J. D.
1966 *Glen Canyon: A Summary.* Anthropological Papers No. 81, Glen Canyon Series No. 31. University of Utah Press, Salt Lake City.

Johnson, A. E., and W. W. Wasley
1966 Archaeological Excavations near Bylas, Arizona. *The Kiva* 31:205–253.

Judd, N. M.
1930 Arizona Sacrifices Her Prehistoric Canals. In *Explorations and Field-Work of the Smithsonian Institution in 1929*, pp. 177–182. Smithsonian Institution, Washington, D.C.

1931 Arizona's Prehistoric Canals from the Air. In *Explorations and Field-Work of the Smithsonian Institution in 1930*, pp. 157–166. Smithsonian Institution, Washington, D.C.

Katari, K., L. Tause, and J. King
2000 t Magnetism: Preliminary Experiments with Natural Sediments. *Earth and Planetary Science Letters* 183:147–160.

Katzer, K.
1989 The Hydrologic Characteristics of the Las Acequias Canals. In *Prehistoric Agricultural Activities on the Lehi-Mesa Terrace: Perspectives on Hohokam Irrigation Cycles,* edited by N. Ackerly and T. K. Henderson, pp. 222–234. Northland Research, Inc., Tempe.

Kearns, T. M., M. K. Polk, and L. S. Teague
1975 Appendix II. Archaeological Resources: Orme Reservoir, Phase II, Verde Arm. In *An Archaeological Survey of the Orme Reservoir,* by Veletta Canouts, pp. 275–373. Archaeological Series No. 92. Arizona State Museum, Tucson.

Kelley, J. C.
1966 Mesoamerica and the Southwestern United States. In *Archaeological Frontiers and External Connections,* edited by G. Willey and G. Ekholm, pp. 95–111. Handbook of Middle American Indians, vol. 4, R. Wauchope, general editor. University of Texas Press, Austin.

Kelly, I. T.
1978 *The Hodges Ruin: A Hohokam Community in the Tucson Basin.* Anthropological Papers No. 30. University of Arizona Press, Tucson.

Kelly, W.
1977 *Cocopa Ethnography.* Anthropological Papers of the University of Arizona No. 29. Tucson.

Kendall, M. B.
1983 Yuman Languages. In *Southwest,* edited by A. Ortiz, pp. 4–12. Handbook of North American Indians, vol. 10, W. C. Sturtevant, general editor. Smithsonian Institution, Washington, D.C.

Khera, S., and P. S. Mariella
1983 Yavapai. In *Southwest,* edited by A. Ortiz, pp. 38–54. Handbook of North American Indians, vol. 10, W. C. Sturtevant, general editor. Smithsonian Institution, Washington, D.C.

King, T. F., P. Parker Hickman, and G. Berg
1977 *Anthropology in Historic Preservation: Caring for Culture's Clutter.* Academic Press, New York.

Kintigh, K. W.
1984 Late Prehistoric Agricultural Strategies and Settlement Patterns in the Zuni Area. In *Prehistoric Agricultural Strategies in the Southwest,* edited by S. K. Fish and P. R. Fish, pp. 215–232. Anthropological Research Papers No. 33. Arizona State University, Tempe.

1985 *Settlement, Subsistence, and Society in Late Zuni Prehistory.* Anthropological Papers No. 44. University of Arizona Press, Tucson.

Landis, D. G.
1991 *Cultural Resource Surveys for the U.S. Highway 180 Location and Design Study, Flagstaff, Arizona.* Soil Systems, Inc., Phoenix.

1993 *Life on the Line: Archaic, Cohonina, and Sinagua Settlements in Western Arizona.* Publications in Archaeology No. 19. Soil Systems, Inc., Phoenix.

Lansing, J. S.
1996 Simulation Modeling of Balinese Irrigation. In *Canals and Communities: Small Scale Irrigation Societies,* edited by J. Mabry, pp. 139–156. University of Arizona Press, Tucson.

Lange, R. C.
1998 *Prehistoric Land-Use and Settlement of the Middle Little Colorado River Valley: The Survey of Homolovi Ruins State Park, Winslow, Arizona.* Arizona State Museum Archaeological Series No. 189. University of Arizona, Tucson.

Lawton, H., and P. Wilke
1979 Ancient Agricultural Systems in Dry Regions. In *Agriculture in Semi-Arid Environments,* edited by A. Hill, G. Cannell, and H. Lawton. Springer-Verlag, New York.

Layhe, R. W. (editor)
1986 *The 1985 Excavations at the Hodges Site, Pima County, Arizona.* Archaeological Series No. 170. Arizona State Museum, University of Arizona, Tucson.

LeBlanc, S. A.
1982 The Advent of Pottery in the Southwest. In *Southwestern Ceramics: A Comparative Review,* edited by A. Schroeder, pp. 27–52. *The Arizona Archaeologist No. 15.* Arizona Archaeological Society, Phoenix.

Lee, B. G.
1975 The McEuen Cave Site Report. Ms. on file, USDI Bureau of Land Management, Safford District, Safford, Arizona.

Leonard, R.
1989 Resource Specialization, Population Growth, and Agricultural Production in the American Southwest. *American Antiquity* 54:491–503.

Lightfoot, D. R., and F. W. Eddy
1995 The Construction and Configuration of Anasazi Pebble-Mulch Gardens in the Northern Rio Grande. *American Antiquity* 60:459–470.

Lightfoot, K. G., and F. Plog
1984 Intensifications along the North Side of the Mogollon Rim. In *Prehistoric Agricultural Strategies in the Southwest,* edited by S. K. Fish and P. R. Fish, pp. 179–195. Anthropological Research Papers No. 33. Arizona State University, Tempe.

Lincoln, T. R.
2000 A Brief History of Salado Archaeology. In *Salado,* edited by J. S. Dean, pp. 17–25. Amerind Foundation Publication, Dragoon, Arizona. University of New Mexico Press, Albuquerque.

Lindauer, O.
1984 Sherd Areas as Loci of Subsistence in the Middle Gila. In *Prehistoric Agricultural Strategies in the Southwest,* edited by S. K. Fish and P. R. Fish, pp. 73–84. Anthropological Research Papers No. 33. Arizona State University, Tempe.

1986 Site AR-03-12-04-118(TNF). In *Small Site Variability in the Payson FLEX Land Exchange,* compiled and edited by C. L. Redman and J. W. Hohmann, pp. 213–230. Anthropological Field Studies No. 11. Office of Cultural Resource Management, Arizona State University, Tempe.

Lindsay, A. J., Jr.
1961 The Beaver Creek Agricultural Community on the San Juan River, Utah. *American Antiquity* 27:174–187.

1987 Anasazi Population Movements to Southeastern Arizona. *American Archaeology* 6:190–198.

Lindsay, A. J., Jr., J. R. Ambler, M. A. Stein, and P. M. Hobler
1968 *Survey and Excavations North and East of Navajo Mountain, Utah, 1959–1962.* Museum of Northern Arizona Bulletin No. 45, Glen Canyon Series No. 8. Northern Arizona Society of Science & Art, Inc., Flagstaff.

Linford, L. D.
1979 *Archaeological Investigations in West-central Arizona: The Cyprus-Bagdad Project.* Archaeological Series No. 136. Arizona State Museum, University of Arizona, Tucson.

Lipe, W. D.
1970 Anasazi Communities in the Red Rock Plateau, Southeastern Utah. In *Reconstructing Prehistoric Pueblo Societies,* edited by W. Longacre, pp. 84–139. University of New Mexico Press, Albuquerque.

1974 A Conservation Model for American Archaeology. *The Kiva* 39:213–245.

Little, B., E. Martin Seibert, J. Townsend, J. H. Sprinkle, Jr., and J. Knoerl
2000 *Guidelines for Evaluating and Registering Archaeological Properties.* National Register Bulletin. USDI National Park Service, Cultural Resources, National Register, History and Education, Washington, D.C.

Loendorf, C., J. C. Ravesloot, M. R. Waters, and K. R. Adams
2002 *McClellan Wash Well Summary.* Pima-Maricopa Irrigation Project Technical Report No. 2002-02. Cultural Resource Management Program, Gila River Indian Community, Sacaton.

Lumholtz, C.
1975 *New Trails in Mexico.* Reprinted. Rio Grande Press, Glorieta, New Mexico. Originally published 1912, Charles Scribner's Sons, New York.

Mabry, J. B.
1998a *Paleoindian and Archaic Sites in Arizona.* Arizona State Historic Preservation Office, Arizona State Parks Board, Phoenix.

1998b *Archaeological Investigations of Early Village Sites in the Middle Santa Cruz Valley: Analyses and Synthesis.* Anthropological Papers No. 19, Pt. 2. Center for Desert Archaeology, Tucson.

2000 The First Sixty-Five Years: Archaeologists' Changing Knowledge and Ideas about the First Farmers in Southeastern Arizona. Ms. on file, Desert Archaeology, Inc., Tucson.

2002 Changing Knowledge and Ideas about the First Farmers in Southeastern Arizona. In *Current Research on the Late Archaic along the U.S.-Mexican Borderlands*, edited by B. J. Vierra. University of Texas Press, Austin. (in press)

Mabry, J. B. (editor)
1996 *Canals and Communities: Small-Scale Irrigation Systems.* Arizona Studies in Human Ecology, University of Arizona Press, Tucson.

Mabry, J. B., and J. P. Holmlund

1998 Canals. In *Archaeological Investigations of Early Village Sites in the Middle Santa Cruz Valley: Analyses and Synthesis,* edited by Jonathan Mabry, pp. 283–298. Anthropological Papers No. 19, Pt. 2. Center for Desert Archaeology, Tucson.

Mackereth, F.J.H.

1971 On the Variation in Direction of the Horizontal Component of Remanent Magnetization in Lake Sediments. *Earth and Planetary Science Letters* 12:332–338.

Macnider, B., and R. Effland, Jr.

1989 *Cultural Resources Overview: The Tonto National Forest.* Cultural Resources Report No. 51. Archaeological Consulting Services, Ltd., Tempe.

Madsen, J. H.

1981 An Archaeological Survey on Cave Creek Northeast of Cave Buttes Reservoir, Paradise Valley, Arizona. Ms. on file, Arizona State Museum, Tucson.

Manje, J. M.

1954 *Luz de Tierra Incognita: Unknown Arizona and Sonora 1693–1721,* translated by H. J. Karns. Arizona Silhouettes, Tucson.

Marmaduke, W. S., and T. K. Henderson

1995 *Archaeology of the Distribution Division of the Central Arizona Project: Thoughts on the History of the Hohokam Culture of Southern Arizona, and on the Practice of Archaeology in the 1990s.* Northland Research, Inc., Flagstaff.

Marmaduke, W. S., and D. G. Robinson

1983 *The Chuichu Survey: Evaluation of Archaeological Sites on the Edge of the Papaguería.* Northland Research, Inc., Flagstaff.

Martin, D. L.

1994 Patterns of Diet and Disease, Health Profiles for the Prehistoric Southwest. In *Themes in Southwestern Prehistory*, edited by G. J. Gumerman, pp. 87–108. School of American Research Press, Santa Fe.

Martin, P. S., and F. Plog

1973 *The Archaeology of Arizona.* Natural History Press, Doubleday, Garden City.

Masse, W. B.

1976 *The Hohokam Expressway Project: A Study of Prehistoric Irrigation in the Salt River Valley, Arizona.* Contributions to Highway Salvage Archaeology in Arizona No. 43. Arizona State Museum, University of Arizona, Tucson.

1979 An Intensive Survey of Prehistoric Dry Farming Systems near Tumamoc Hill in Tucson, Arizona. *The Kiva* 45:141–186.

1980a The Hohokam of the Lower San Pedro Valley and the Northern Papaguería: Continuity and Variability in Two Regional Populations. In *Current Issues in Hohokam Prehistory,* edited by D. Doyel and F. Plog, pp. 205–223. Anthropological Research Paper No. 23. Arizona State University, Tempe.

1980b *Excavations at Gu Achi: A Reappraisal of Hohokam Settlement and Subsistence in the Arizona Papaguería.* Publications in Anthropology No. 12. Western Archeological and Conservation Center, USDI National Park Service, Tucson.

1981 Prehistoric Irrigation Systems in the Salt River Valley, Arizona. *Science* 214:208–215.

1990 Whimsy Flat: AZ T:16:71(ASM). In *Archaeology of the Ak-Chin Indian Community West Side Farms Project: Subsistence Studies and Synthesis and Interpretation,* edited by R. E. Gasser, C. K. Robinson, and C. D. Breternitz, pp. 12.1–12.37. Publications in Archaeology No. 9, Vol. 5. Soil Systems, Inc., Phoenix.

1991a The Quest for Subsistence Sufficiency and Civilization in the Sonoran Desert. In *Chaco and Hohokam: Prehistoric Regional Systems in the American Southwest,* edited by P. L. Crown and W. J. Judge, pp. 195–225. School of American Research Press, Santa Fe.

*Masse's chapter discusses both irrigated and non-irrigated agricultural techniques of the Hohokam.

1991b Systems and Systematics: A Critique of Interdisciplinary Study of Hohokam Irrigation. In *Prehistoric Irrigation in Arizona: Symposium 1988*, edited by C. D. Breternitz, pp. 155–172. Publication in Archaeology No. 17. Soil Systems, Inc., Phoenix

Masse, W. B. (editor)
1987 *Archaeological Investigations of Portions of the Las Acequias–Los Muertos Irrigation System: Testing and Partial Data Recovery within the Tempe Section of the Outer Loop Freeway System, Maricopa County, Arizona.* Archaeological Series No. 176. Arizona State Museum, University of Arizona, Tucson.

Masse, W. B., L. M. Gregonis, and M. C. Slaughter
1997 Corridor, Frontier, or Cultural Crossroads: Preclassic Period Archaeology of the Lower San Pedro Valley. In *The Archaeology of a Land Between: Regional Dynamics in the Prehistory and History of Southeastern Arizona,* edited by H. D. Wallace. Amerind Foundation, Dragoon, Arizona, and University of New Mexico Press, Albuquerque. In press.

Masse, W. B., and R. W. Layhe
1987 Testing and Data Recovery at La Cuenca del Sedimento, AZ U:9:68(ASM). In *Archaeological Investigations of Portions of the Las Acequias–Los Muertos Irrigation System: Testing and Partial Data Recovery within the Tempe Section of the Outer Loop Freeway System, Maricopa County, Arizona,* edited by W. B. Masse, pp. 83–121. Archaeological Series No. 176. Arizona State Museum, University of Arizona, Tucson.

Mathien, F. J., and R. H. McGuire (editors)
1986 *Ripples in the Chichimec Sea: New Considerations of Southwestern-Mesoamerican Interactions.* Southern Illinois University Press, Carbondale.

Matson, R. G.
1991 *The Origins of Southwestern Agriculture.* University of Arizona Press, Tucson.

*This is a far-ranging and useful reference on the appearance of agriculture in the Southwest. Included in the discussion are considerations of non-irrigation agricultural activities.

McGregor, J. C.
1950 Excavation of Cohonina Sites, 1949. *Plateau* 22:68–74.

1951 *The Cohonina Culture of Northwestern Arizona.* University of Illinois Press, Urbana.

1958 *Plateau* 31:33–36.

1965 *Southwestern Archaeology.* 2nd ed. University of Illinois Press, Urbana.

1967 *The Cohonina Culture of Mount Floyd, Arizona.* Studies in Anthropology No. 5. University of Kentucky Press, Lexington.

McGuire, R. H.
1982 Problems in Culture History. In *Hohokam and Patayan: Prehistory of Southwestern Arizona,* edited by R. H. McGuire and M. B. Schiffer, pp. 153–222. Academic Press, New York.

1984 The Boserup Model and Agricultural Intensification in the United States Southwest. In *Prehistoric Agricultural Strategies in the Southwest*, edited by S. K. Fish and P. R. Fish, pp. 327–334. Anthropological Research Papers No. 33. Arizona State University, Tempe.

1991 On the Outside Looking In: The Concept of Periphery in Hohokam Archaeology. In *Exploring the Hohokam: Prehistoric Desert Peoples of the American Southwest,* edited by G. J. Gumerman, pp. 347–382. Amerind Foundation New World Studies Series No. 1. Amerind Foundation, Dragoon, Arizona, and University of New Mexico Press, Albuquerque.

McGuire, R. H., and M. B. Schiffer
1982 *Hohokam and Patayan: Prehistory of Southwestern Arizona.* Academic Press.

McKie, J. M.
2000 A Brief Look at "Prescott Tradition" Site Variation and Settlement in Ponderosa Pine Habitats of the Upper Hassayampa River Area. In *Archaeology in West-Central Arizona: Proceedings of the 1996 Arizona Council Prescott Conference*, edited by T. N. Motsinger, D. R. Mitchell, and J.M. McKie. Sharlot Hall Museum Press, Prescott, Arizona.

McNish, A. G., and E. A. Johnson
1938 Magnetization of Unmetamorphosed Varves and Marine Sediments. *Terrestrial Magnetism and Atmospheric Electricity* 43:401–407.

Meltzer, D. J., and M. B. Collins
1987 Prehistoric Water Wells on the Southern High Plains: Clues to Altithermal Climate. *Journal of Field Archaeology* 14:9–28.

Midvale, F.
1946 *Prehistoric Ruins and Irrigation Features in the Horseshoe Reservoir Region of the Verde River, Central Arizona.* Map. On file, Midvale Collection, Arizona Collection, Hayden Library, Arizona State University, Tempe.

1963 *The Prehistoric Irrigation of the Casa Grande Ruins Area of the Gila River in Southern Arizona.* Map. On file, Midvale Collection, Book XII, Arizona Collection, Hayden Library, Arizona State University, Tempe.

1964 Letter from Mrs. Annie Sanders, Southwest Archaeological Center Librarian Assistant. On file, Western Archeological and Conservation Center, USDI National Park Service, Tucson.

1965 Prehistoric Irrigation of the Casa Grande Ruins Area. *The Kiva* 30:82–86.

1966 Prehistoric Irrigation of the Salt River Valley. Map on file, Arizona Collection, Hayden Library, Arizona State University, Tempe.

1968 Prehistoric Irrigation in the Salt River Valley, Arizona. *The Kiva* 34:28–34.

1969 *Prehistoric Irrigation of the New River Area of Central Arizona.* Map. On file, Midvale Collection, Arizona Collection, Hayden Library, Arizona State University, Tempe.

1970 Prehistoric "Canal-Irrigation" in the Buckeye Valley and Gila Bend Areas in Western Maricopa County, Arizona. Paper presented at the Pecos Conference, Santa Fe.

1971 Collection of notes, photographs, and maps. On file, Department of Anthropology, Arizona State University, Tempe.

1974 Prehistoric Ruins and Irrigation in the Eastern Buckeye Valley. *The Arizona Archaeologist* 4:37–39.

Miksicek, C. H.

1983 Plant Remains from Agricultural Features. In *Hohokam Archaeology along the Salt-Gila Aqueduct, Central Arizona Project: Specialized Activity Sites*, edited by L. S. Teague and P. L. Crown, pp. 605–620. Archaeological Series No. 150, Vol. 3. Arizona State Museum, University of Arizona, Tucson.

1984 Historic Desertification, Prehistoric Vegetation Change, and Hohokam Subsistence in the Salt-Gila Basin. In *Hohokam Archaeology along the Salt Gila Aqueduct, Central Arizona Project: Environment and Subsistence,* edited by L. S. Teague and P. L. Crown, pp. 53–80. Archaeological Series No. 150, Vol. 7. Arizona State Museum, University of Arizona, Tucson.

1989 Snails, Seeds and Charcoal: Macrofossils from the Las Acequias Canal System. In *Prehistoric Agricultural Activities on the Lehi-Mesa Terrace: Perspectives on Hohokam Irrigation Cycles,* edited by N. W. Ackerly and T. K. Henderson, pp. 235–262. Northland Research, Inc., Flagstaff.

1995 Canal Mollusks and Plant Remains. In *Archaeology at the Head of the Scottsdale Canal System: Canal and Synthetic Studies*, edited by M. R. Hackbarth, T. K. Henderson, and D. B. Craig, pp. 121–131. Anthropological Papers No. 95-1, Vol. 3. Northland Research, Inc., Tempe.

Miller, J. A.

1990 *Subsistence Practices at Shoofly Village, AZ:O:11:6: The Botanical Evidence.* Unpublished Master's thesis, Department of Anthropology, Arizona State University, Tempe.

1994 Pueblo Grande Flotation, Macrobotanical, and Wood Charcoal Analysis. In *The Pueblo Grande Project: Environment and Subsistence*, edited by S. Kwiatkowski, pp. 127–204. Publication in Archaeology No. 20, Vol. 5. Soil Systems, Inc., Phoenix.

Mindeleff, C.

1896 Aboriginal Remains in Verde Valley, Arizona. In *Thirteenth Annual Report of the Bureau of Ethnology to the Secretary of the Smithsonian Institution 1891-'92*, by J. W. Powell, pp. 185–261. U.S. Government Printing Office, Washington, D.C.

Mindeleff, V.

1989 *A Study of Pueblo Architecture: Tusayan and Cibola.* Reprinted. Smithsonian Institution, Washington, D.C. Originally published 1891.

Mitalsky, F. [F. Midvale]

1935 *A General Map of the Central Pima Country on the Gila.* Map. On file, Arizona Collection, Hayden Library, Arizona State University, Tempe.

Mitchell, D. R.

1986 *Hohokam, Mogollon, and Western Pueblo Settlement Systems in the San Carlos River Valley.* Archaeological Research Services, Inc., Tempe.

Mitchell, D. R. (editor)

1998 *The Desert Mountain Properties Archaeological Testing Project, Scottsdale, Arizona.* SWCA Cultural Resources Report No. 98-44. Phoenix.

Mitchell, D. R., and T. N. Motsinger (editors)

1998 *Life at the River's Edge: Hohokam Irrigation and Settlement along the Red Mountain Freeway between the Price Freeway and McKellips Road.* SWCA Archaeological Report No. 97-23. Tucson.

Mobley-Tanaka, J. L., and F. W. Eddy

1995 Check Dams at Chimney Rock Mesa: Agricultural Strategies in a Marginal Environment. *Kiva* 60:429–442.

Monkhouse, F. J.
1965 *A Dictionary of Geography.* Aldine, Chicago.

Motsinger, T. N.
1993 *Archaeological Investigations at the Gila Butte Site: Hohokam Irrigation and Economic Systems along the Gila River, Arizona.* SWCA Archaeological Report No. 93-84. Phoenix.

Motsinger, T. N., D. R. Mitchell, and J. M. McKie (editors)
2000 *Archaeology in West-Central Arizona: Proceedings of the 1996 Arizona Archaeological Council Prescott Conference.* Sharlot Hall Museum Press, Prescott.

Motsinger, T. N., D. R. Mitchell, and J. M. McKie
2000 A Prescott Primer: Introduction to the Archaeology and the Conference. In *Archaeology in West-Central Arizona: Proceedings of the 1996 Arizona Archaeological Council Prescott Conference,* edited by T. N. Motsinger, D. R. Mitchell, and J. M. McKie, pp. 1–11. Sharlot Hall Museum Press, Prescott.

Muro, M.
1998 New Finds Explode Old Views of the American Southwest. *Science* 279:653–654.

Myrick, D. F.
1980 *Railroads of Arizona: Phoenix and the Central Roads.* vol. 2. Howell-North, San Diego.

Nabhan, G. P.
1979 The Ecology of Floodwater Farming in Arid Southwestern North America. *Agro-Ecosystems* 5:245–255.

1982 *The Desert Smells Like Rain: A Naturalist in Papago Indian Country.* North Point Press, San Francisco.

1983a The Ecology of Floodwater Farming in Arid Southwestern North America. *Agro-Ecosystems* 5:245–255.

1983b Papago Fields: Arid Lands Ethnobotany and Agricultural Ecology. Unpublished Ph.D. Dissertation, Office of Arid Lands Studies, University of Arizona, Tucson.

1986a Papago Indian Desert Agriculture and Water Control in the Sonoran Desert, 1697–1934. *Applied Geography* 6:43–59.

1986b 'Ak-Cin' Arroyo Mouth and the Environmental Setting of the Papago Indian Fields in the Sonoran Desert. *Applied Geography* 6:61–75.

1986c *Gathering the Desert.* University of Arizona Press, Tucson.

1989 *Enduring Seeds.* North Point Press, San Francisco.

*Nabhan's articles contain important discussions of O'odham non-irrigation agricultural practices. Of note is the discussion of what the term *ak-chin* means.

Nabhan, G. P., and W. B. Masse
1986 Floodwater Agriculture in the Sonoran Desert: Ethnographic and Archaeological Perspectives. Paper presented at the 51st Annual Meeting of the Society for American Archaeology, New Orleans.

National Park Service
1982 *Guidelines for Completing National Register Criteria for Evaluation.* National Register Bulletin No. 15. U.S. Department of the Interior, Washington, D.C.

1986 *Guidelines for Completing National Register of Historic Places Forms.* National Register Bulletin No. 16. U.S. Department of the Interior, Washington, D.C.

1996 *Thematic Framework.* USDI National Park Service, Cultural Resources, National Register, History and Education, Washington, D.C.

1997 *How to Apply the National Register Criteria for Evaluation.* National Register Bulletin. USDI National Park Service, Cultural Resources, National Register, History and Education, Washington, D.C.

Neely, J. A.
1974 *The Prehistoric Lunt and Stove Canyon Sites, Point of Pines, Arizona.* Unpublished Ph.D. dissertation, Department of Anthropology, University of Arizona, Tucson.

1995 *A Progress Report on the Survey and Mapping of Six (6) Water-Management Systems (AZ C:1:10:33–37 [ASM]) in the Vicinity of Pima, Arizona.* Submitted to Arizona State Museum. Department of Anthropology, University of Texas, Austin.

2001 Prehistoric Agricultural Fields and Water Management Technology of the Safford Valley, Southeastern Arizona. *Antiquity* 75(290).

Neely, J. A., and J. S. Crary
1997 An Archaeological Overview of Upper (Northern) Southeastern Arizona: The Formative and Classic Periods. In *The Archaeology of a Land Between: Regional Dynamics in the Prehistory and History of Southeastern Arizona,* edited by H. D. Wallace. Amerind Foundation, Dragoon, Arizona, and University of New Mexico Press, Albuquerque. In press.

Neely, J. A., and J. R. Rinker
1997 Foothill Irrigation and Domestic Water Systems of the Safford Valley, Southeastern Arizona: A Progress Report on the 2nd Field Season of Survey and Mapping of Water-Management Systems and Associated Sites in the Vicinity of Pima, Arizona. Ms. on file, Arizona State Museum, University of Arizona, Tucson

Neily, R. B.
1991 *Archaeological Survey of the Western Half of the Gila Drain Borrow Area, Gila River Indian Community, Maricopa County, Arizona.* ACS Project No. 88-940A. Archaeological Consulting Services, Ltd., Tempe.

Neily, R. B., M. Brodbeck, and C. M. Peterson
1999 *A Cultural Resource Survey of the Borderlands-West Area, District 6, Gila River Indian Community, Maricopa County, Arizona.* CRMP Technical Report No. 98-10. Cultural Resource Management Program, Gila River Indian Community, Sacaton.

Neily, R. B., C. Broyles, M. Brodbeck, S. R. James, and J. Touchin
1999 *A Cultural Resource Survey of the Santan Extension (Memorial) Management Area, Pima-Maricopa Irrigation Project, Gila River Indian Community, Maricopa and Pinal Counties, Arizona.* P-MIP Report No. 5. Cultural Resource Management Program, Gila River Indian Community, Sacaton.

Neily, R. B., R. Ciolek-Torrello, and M. A. Sterner
1999 Previous Research and Culture History. In *Investigations at Sunset Mesa Ruin: Archaeology at the Confluence of the Santa Cruz and Rillito Rivers, Tucson, Arizona.* Technical Series No. 66. Statistical Research, Inc., Tucson.

Neily, R. B., J. S. Crary, G. M. Kinkade, and S. Germick
1993 The Owens-Colvin Site Revisited: A Preliminary Report of the Excavations at a Bylas Phase Settlement near Eden, Arizona. Paper presented at the 66th Pecos Conference, Springerville, Arizona.

Neily, R. B., B. G. Randolph, S. R. James, and M. Brodbeck
2000 *An Archaeological Assessment of the Southwestern Portion of the Santan Management Area, Pima-Maricopa Irrigation Project (P-MIP), Gila River Indian Community, Arizona.* P-MIP Report No. 10. Cultural Resource Management Program, Gila River Indian Community, Sacaton.

Neitzel, J.
1991 Hohokam Material Culture and Behavior: The Dimensions of Organizational Change. In *Exploring the Hohokam: Prehistoric Desert People of the American Southwest,* edited by G. J. Gumerman, pp. 194–198. University of New Mexico Press, Albuquerque.

Nelson, B. A.
2000 Salado at the End of the Twentieth Century. In *Salado,* edited by J. S. Dean, pp. 321–326. Amerind Foundation Publication, Dragoon, Arizona. University of New Mexico Press, Albuquerque.

Nelson, B. A., and S. A. LeBlanc
1986 *Short-Term Sedentism in the American Southwest: The Mimbres Valley Salado.* University of New Mexico Press, Albuquerque.

Nelson, R. S.
1986 Pochtecas and Prestige: Mesoamerican Artifacts in Hohokam Sites. In *Ripples in the Chichimec Sea: New Considerations of Southwestern-Mesoamerican Interactions,* edited by F. J. Mathien and R. H. McGuire, pp. 154–182. Southern Illinois University Press, Carbondale.

Netting, R. McC.
1993 *Smallholders, Householders: Farm Families and the Ecology of Intensive, Sustainable Agriculture.* Stanford University Press, Stanford.

Nials, F. L., and S. K. Fish
1988 Canals and Related Features. In *The 1982–84 Excavations at Las Colinas: The Site and Its Features,* by D. A. Gregory, W. L. Deaver, S. K. Fish, R. Gardiner, R. W. Layhe, F. L. Nials, and L. S. Teague, pp. 275–305. Arizona State Museum Archaeological Series No. 162, Vol. 2. Tucson.

Nials, F. L., and D. A. Gregory
1989 Irrigation Systems in the Lower Salt River Valley. In *The 1982–1984 Excavations at Las Colinas: Environment and Subsistence,* by D. A. Graybill, D. A. Gregory, F. L. Nials, S. K. Fish, R. E. Gasser, C. H. Miksicek, and C. R. Szuter, pp. 39–58. Archaeological Series No. 162, Vol. 5. Arizona State Museum, University of Arizona, Tucson.

Nials, F. L., D. A. Gregory, and D. A. Graybill
1989 Salt River Streamflow and Hohokam Irrigation Systems. In *The 1982–84 Excavations at Las Colinas: Environment and Subsistence,* by D. A. Graybill, D. A. Gregory, F. L. Nials, S. K. Fish, R. E. Gasser, C. H. Miksicek, and C. R. Szuter, pp. 59–76. Arizona State Museum Archaeological Series No. 162, Vol. 5. Tucson.

Nicholas, L. M.
1981 *Irrigation and Sociopolitical Development in the Salt River Valley, Arizona: An Examination of Three Prehistoric Canal Systems.* Unpublished Master's thesis, Department of Anthropology, Arizona State University, Tempe.

Nicholas, L. M., and J. Neitzel
1984 Canal Irrigation and Sociopolitical Organization in the Lower Salt River Valley: A Diachronic Analysis. In *Prehistoric Agricultural Strategies in the Southwest,* edited by S. K. Fish and P. R. Fish, pp. 161–178. Anthropological Research Papers No. 33. Arizona State University, Tempe.

Nichols, R.
1975 Archeomagnetic Study of Anasazi-Related Sediments of Chaco Canyon, New Mexico. Unpublished Master's thesis, Department of Geosciences, University of Oklahoma, Norman.

Nickens, P. R.
1976 Stature Reduction as an Adaptive Response to Food Production in Mesoamerica. *Journal of Archaeological Science* 3:31–41.

North, C., A. Lack, and M. S. Foster
2001 *A Class III Cultural Resources Inventory of the Proposed Preserve at Goldfield Ranch Subdivision, Maricopa County, Arizona.* SWCA Archaeological Report No. 01-272. Phoenix.

Officer, J. E.
1987 *Hispanic Arizona, 1536–1856.* University of Arizona Press, Tucson.

Ortloff, C. R., R. A. Feldman, and M. E. Moseley
1985 Hydraulic Engineering and Historical Aspects of the Pre-Columbian Intravalley Canal Systems of the Moche Valley, Peru. *Journal of Field Archaeology* 12:77–98.

Palacios-Fest, M.
1994 Nonmarine Ostracode Shell Chemistry from Ancient Hohokam Irrigation Canals in Central Arizona: A Paleohydrochemical Tool for the Interpretation of Prehistoric Occupation in the North American Southwest. *Geoarchaeology: An International Journal* 9:1–30.

1997 Paleoenvironmental Reconstructions of Human Activity in Central Arizona Using Shell Chemistry of Hohokam Canal Ostracodes. *Geoarchaeology: An International Journal* 12:211–226

Parry, T. E.
1981 *Cultural Dynamics on a Prehistoric Frontier: A Study of Culturally Mixed Sites in Medicine Valley, Northern Arizona.* Unpublished Master's Thesis, Department of Anthropology, Northern Arizona University, Flagstaff.

Parsons, J. R., and M. H. Parsons
1990 *Maguey Utilization in Highland Central Mexico: An Archaeological Ethnography.* Anthropological Papers No. 82. Museum of Anthropology, University of Michigan, Ann Arbor.

Patrick, H. R.
1903 *The Ancient Canal Systems and Pueblos of the Salt River Valley, Arizona.* Bulletin No. 1. Phoenix Free Museum, Phoenix.

Phillips, B. G.
1998 *Prehistoric Floodwater Agriculture along the Middle Cave Creek, Maricopa County, Arizona.* Cultural Resource Report No. 103. Archaeological Consulting Services, Ltd., Tempe.

*This report provides some useful information on the integrity of non-irrigation agricultural features.

Phillips, B. G., and D. B. Craig
2001 Canals. In *The Grewe Archaeological Research Project: Project Background and Feature Descriptions,* edited by D. B. Craig, pp. 146–162. Anthropological Papers No. 99-1, Vol. 1. Northland Research, Inc., Flagstaff and Tempe.

Pilles, P. J., Jr.
n.d. A Cultural Resource Overview of the Northern Sinagua. Ms. on file, USDA Forest Service, Coconino National Forest, Flagstaff.

1969 Habitation and Field Houses near Winona and Angell, Arizona. *The Kiva* 34:90–102.

1979 Sunset Crater and the Sinagua: A New Interpretation. In *Volcanic Activity and Human Ecology*, edited by P. D. Sheets and D. K. Grayson, pp. 459–485. Academic Press, New York.

1981 A Review of Yavapai Archaeology. In *The Protohistoric Period in the North American Southwest, A.D. 1450-1700,* edited by D. R. Wilcox and W. B. Masse, pp. 163–182. Anthropological Research Papers No. 24. Arizona State University, Tempe.

Plog, F.
1984 Regional Perspectives on the Western Anasazi. *American Archaeology* 4:162–170.

Plog, F., and C. Garrett
1972 Explaining Variability in Prehistoric Southwestern Water Control Systems. In *Contemporary Archaeology: A Guide to Theory and Contributions*, edited by M. Leone, pp. 280–288. Southern Illinois University Press, Carbondale.

Potter, J. M.
2000 Project Synthesis. In *Tributaries, Terraces, and Tinajas: Prehistoric Cultural Variation on Three Drainages near New River, Maricopa County, Arizona*, edited by J. M. Potter and L. A. Neal, pp. 167–176. SWCA Anthropological Research Paper No. 7. Flagstaff.

Potter, J. M., and R. R. Fox
2000 Site Descriptions. In *Tributaries, Terraces, and Tinajas: Prehistoric Cultural Variation on Three Drainages near New River, Maricopa County, Arizona*, edited by J. M. Potter and L. A. Neal, pp. 23–77. SWCA Anthropological Research Paper No. 7. Flagstaff.

Purcell, D. E., L. S. Cummings, K. Puseman, and T. E. Moutoux
1997 Hohokam Non-Irrigation Agriculture in the Middle and Upper Gila Valley. In *The Eastern Mining Area Project Coolidge to Hayden Segment Data Recovery: Hohokam Agriculture in the Middle and Upper Gila River Valley of Pinal County, Arizona,* edited by D. E. Purcell, pp. 5.1–5.44. SWCA Archeological Report No. 97-47. Flagstaff.

Raab, L. M.
1975 A Prehistoric Water Reservoir from Santa Rosa Wash, Southern Arizona. *The Kiva* 40:295–308.

Rankin, A.
1988 Floodwater Canal Irrigation Agricultural Systems in the Hohokam Northern Periphery: The Waddell Project New River Area. Paper presented at the Arizona Archaeological Council "Prehistoric Irrigation in Arizona" symposium, Phoenix.

1989 Agricultural Features. In *Settlement, Subsistence, and Specialization in the Northern Periphery: The Waddell Project,* edited by M. Green, pp. 949–979. Report No. 65. Archaeological Consulting Services, Ltd., Tempe.

Rankin, A., and K. Katzer
1989 Agricultural Systems in the ACS Waddell Project Area. In *Settlement. Subsistence, and Specialization in the Northern Periphery: The Waddell Project,* edited by M. Green, pp. 981–1019. Report No. 65. Archaeological Consulting Services, Ltd., Tempe.

*Several chapters in this volume provide very useful discussions of non-irrigation agriculture.

Ravesloot, J. C.

1984 A Small Hohokam Site, AZ T*54. In *Prehistoric Cultural Development in Central Arizona: Archaeology of the Upper New River Region,* edited by P. M. Spoerl and G. J. Gumerman, pp. 101–130. Center for Archaeological Investigations Occasional Paper No. 5. Southern Illinois University, Carbondale.

Ravesloot, J. C., and S. M. Whittlesey

1987 Inferring the Protohistoric Period in Southern Arizona. In *The Archaeology* of *the San Xavier Bridge Site (AZ BB:13:14), Tucson Basin, Southern Arizona,* edited by J. C. Ravesloot, pp. 81–98. Archaeological Series No. 171. Arizona State Museum, University of Arizona, Tucson.

Ravesloot, J. C., and M. K. Woodson

2000 The Role of Anthropology, Archaeology, and History in Native American Water Rights Claims. Paper presented at the annual meeting of the American Anthropological Association, San Francisco.

Rea, A.

1981 The Ecology of Pima Fields. *Environment Southwest* 484:8–15.

1983 *Once a River: Bird Life and Habitat Changes on the Middle Gila.* University of Arizona Press, Tucson.

1997 *At the Desert's Green Edge: An Ethnobotany of the Gila River Pima.* University of Arizona Press, Tucson.

Redman, C. L.

1999 *Human Impact on Ancient Environments.* University of Arizona Press, Tucson.

Redman, C. L., and J. Hohmann

1986 *Small Site Variability in the Payson Region: The FLEX Land Exchange.* Anthropological Field Studies No. 11. Office of Cultural Resource Management, Arizona State University, Tempe.

Reichart, K., and G. P. Nabhan

1980 Ecology and Ethnobotany of Dead Valley. In *Prehistory in Dead Valley, East-Central Arizona: The TG&E Springerville Project,* edited by D. Doyel and S. Debowski, pp 19–31. Arizona State Museum Archaeological Series No. 144. Tucson.

Reid, J. J.

1989 A Grasshopper Perspective on the Mogollon of the Arizona Mountains. In *Dynamics of Southwestern Prehistory,* edited by L. S. Cordell and G. J. Gumerman, pp. 65–98. Smithsonian Institution Press, Washington, D.C.

Reid, J. J., and S. M. Whittlesey

1997 *The Archaeology of Ancient Arizona.* University of Arizona Press, Tucson.

Rice, G. E.

1990 An Intellectual History of the Salado Concept. In *A Design for Salado Research*, edited by G. E. Rice, pp. 21–29. Roosevelt Monograph Series No. 1. Anthropological Field Studies, Office of Cultural Resource Management, Department of Anthropology, Arizona State University, Tempe.

1998 War and Water: An Ecological Perspective on Hohokam Irrigation. *Kiva* 63:263–301.

Rice, G., D. Wilcox, K Rafferty, and J. Schoenwetter

1979 An Archaeological Test of Sites in the Gila Butte–Santan Region, South-Central Arizona. Anthropological Papers No. 18. Arizona State University, Tempe.

Rinker, J. R.

1998 *The Bryce-Smith Project: Irrigated Agriculture and Habitation from A.D. 1000 to 1450, Lefthand Canyon, Safford Valley, Arizona.* Unpublished Master's thesis, Department of Anthropology, University of Texas, Austin.

Robinson, W. J., and C. M. Cameron
1991 *A Directory of Tree-Ring Dated Prehistoric Sites in the American Southwest.* Laboratory of Tree-Ring Research, University of Arizona, Tucson.

Rodgers, J. B.
1976 *An Archaeological Investigation of Buckeye Hills East, Maricopa County, Arizona.* Anthropological Research Paper No. 10. Arizona State University, Tempe.

1977 *Archaeological Investigations of the Granite Reef Aqueduct, Cave Creek Archaeological District, Arizona.* Anthropological Research Paper No. 12. Arizona State University, Tempe.

1978 The Fort Mountain Complex, Cave Buttes, Arizona. In *Limited Activity and Occupation Sites: A Collection of Conference Papers,* edited by A. E. Ward, pp. 147–163. Contributions to Anthropological Studies No. 1. Center for Anthropological Studies, Albuquerque.

1985 Prehistoric Agricultural Variability in the Hohokam Northern Periphery. In *Hohokam Settlement and Economic Systems in the Central New River Drainage, Arizona,* edited by D. E. Doyel and M. D. Elson, pp. 249–296. Publications in Archaeology No. 4. Soil Systems, Inc., Phoenix.

Rogers, M. J.
1929 *Report on an Archaeological Reconnaissance in the Mojave Sink Region.* San Diego Museum of Man Archaeological Papers No. 1, Vol. 1. San Diego.

1939 *Early Lithic Industries of the Lower Basin of the Colorado River and Adjacent Desert Areas.* San Diego Museum of Man Archaeological Papers No. 3. San Diego.

1945 An Outline of Yuman Prehistory. *Southwestern Journal of Anthropology* 1:167–198.

1958 San Dieguito Implements from the Terraces of the Rincon-Patano and Rillito Drainage System. *The Kiva* 24:1–23.

Roth, B. J.
1992 Sedentary Agriculturalists or Mobile Hunter-Gatherers? Evidence on the Late Archaic Occupation of the Northern Tucson Basin. *Kiva* 57:291–314.

1993 Changing Perceptions of the Late Archaic: An Example from the Southern Southwest. *North American Archaeologist* 14:123–137.

1995 Late Archaic Occupation of the Upper Bajada: Excavations at AZ AA:12:84(ASM), Tucson Basin. *Kiva* 61:189–207.

Roubicek, D., E. Cummings, and G. Hartmann
1973 *A Reconnaissance and Preliminary Evaluation of the Archaeology of Rancho Romero.* Archaeological Series No. 24. Arizona State Museum, University of Arizona, Tucson.

Russell, F.
1975 *The Pima Indians.* Reprinted. University of Arizona Press, Tucson. Originally published 1908, Twenty--sixth Annual Report of the Bureau of American Ethnology, 1904–1905, U.S. Government Printing Office, Washington, D.C.

*Includes discussion of Pima agriculture and food gathering.

Russell, S. C.
1977 The Prehistoric Agricultural Potential of Copper Basin. In *Archaeology in Copper Basin, Yavapai County, Arizona: Model Building for the Prehistory of the Prescott Region,* by M. D. Jeter, pp. 330–338. Anthropological Research Papers No. 11. Arizona State University, Tempe.

Samples, T., J. A. Hanson, and D. R. Wilcox
1990 Cohonina Archaeology: Past and Present. Paper presented at the 55th Annual Meeting of the Society for American Archaeology, Las Vegas.

Sanders, D.
1990 Excavation and Analysis of the Day Mine Rockshelter. Ms. on file, USDI Bureau of Land Management, Safford, Arizona.

Sandor, J. A., P. L. Gersper, and J. W. Hawley
1990 Prehistoric Agricultural Terraces and Soils in the Mimbres Area, New Mexico. *World Archaeology* 22:70–86.

Sauer, C. O., and D. D. Brand
1930 Pueblo Sites in Southeastern Arizona. *University of California Publications in Geography* 3:415–459.

Sayles, E. B.
1945 *The San Simon Branch, Excavations in Cave Creek and in the San Simon Valley: Material Culture.* Medallion Papers No. 34, Vol. 1. Gila Pueblo, Globe, Arizona.

1983 *The Cochise Cultural Sequence in Southeastern Arizona.* Anthropological Papers No. 42. University of Arizona Press, Tucson.

Sayles, E. B., and E. Antevs
1941 *The Cochise Culture.* Medallion Papers No. 29. Gila Pueblo, Globe, Arizona.

Schiffer, M. B.
1987 *Formation Processes of the Archaeological Record.* University of New Mexico Press, Albuquerque.

Schoeneberger, P. J., D. A. Wysocki, E. C. Benham, and W. D. Broderson
1998 *Field Book for Describing and Sampling Soils.* National Soil Survey Center, Natural Resources Conservation Service, Lincoln, Nebraska.

Schoenwetter, J. and A. E. Dittert, Jr.
1968 An Ecological Interpretation of Anasazi Settlement Patterns. In *Anthropological Archaeology in the Americas*, edited by B. J. Meggers, pp. 41–66. Anthropological Society of Washington, Washington, D.C.

Schroeder, A. H.
1940 *A Stratigraphic Survey of Pre-Spanish Trash Mounds of the Salt River Valley, Arizona.* Unpublished Master's thesis, Department of Anthropology, University of Arizona, Tucson.

1943 Prehistoric Canals in the Salt River Valley, Arizona. *American Antiquity* 8:380–386.

1958 *Montezuma Castle National Monument, Arizona.* Historical Handbook Series No. 27. USDI National Park Service, Washington, D.C.

1960 *The Hohokam, Sinagua and Hakataya.* Archives of Archaeology No. 5. USDI National Park Service, Southwest Region, Santa Fe.

1961 *The Archeological Excavations at Willow Beach, Arizona, 1950.* Anthropological Papers No. 50. University of Utah, Salt Lake City.

1966 Pattern Diffusion from Mexico into the Southwest after A.D. 600. *American Antiquity* 31:683–704.

1979 Prehistory: Hakataya. In *Southwest*, edited by A. Ortiz, pp. 100–107. Handbook of North American Indians, vol. 9, W. C. Sturtevant, general editor. Smithsonian Institution, Washington, D.C.

Schwartz, D. W.
1956 The Havasupai, 600 A.D.–1955 A.D.: A Short Culture History. *Plateau* 28:77–85.

1960 Archaeological Investigations in the Shinumo Area of the Grand Canyon, Arizona. *Plateau* 32:61–67.

Seymour, G. R.
1998 The Civilian Conservation Corps in Arizona: A Context for Erosion-Control Features. *Kiva* 63:359–377.

Sharrock, F. W., D. S. Dibble, and K. M. Anderson
1961 The Creeping Dune Irrigation Site in Glen Canyon, Utah. *American Antiquity* 27:188–202.

Sheppard, P. R., A. C. Comrie, G. D. Packin, K. Angersbach, and M. K. Hughes
1999 *The Climate of the Southwest.* Climas Report No. CL 1-99. Institute for the Study of Planet Earth, University of Arizona, Tucson.

Sheridan, T. E.
1986 *Los Tucsonenses: The Mexican Community in Tucson, 1854–1941.* University of Arizona Press, Tucson.

Simonis, D. E.
2000 Western Prescott and Cohonina Traditions. In *Archaeology in West-Central Arizona: Proceedings of the 1996 Arizona Archaeological Council Prescott Conference*, edited by T. N. Motsinger, D. R. Mitchell, and J. M. McKie, pp. 195–203. Sharlot Hall Museum Press, Prescott.

Simmons, A.
1986 New Evidence for the Early Use of Cultigens in the American Southwest. *American Antiquity* 51:73–89.

Sires, E. W.
1983 Archaeological Investigations at Las Fosas (AZ U:15:19). In *Hohokam Archaeology along the Salt-Gila Aqueduct, Central Arizona Project: Habitation Sites on the Gila River,* edited by L. S. Teague and P. L. Crown, pp. 493–658 Archaeological Series No. 150, Vol. 6. Arizona State Museum, University of Arizona, Tucson.

1987 Hohokam Architectural Variability and Site Structure during the Sedentary-Classic Transition. In *The Hohokam Village: Site Structure and Organization,* edited by D. E. Doyel, pp. 171–182. American Association for the Advancement of Science, Glenwood Springs, Colorado.

Slatter, E. D., F. T. Plog, and S. Plog
1976 Chevelon Site Data. In *Chevelon Archaeological Research Project, 1971–1972*, edited by F. T. Plog, J. N. Hill, and D. W. Read, pp. 28–40. Archaeological Survey Monograph No. 11. Department of Anthropology, University of California, Los Angeles.

Slaughter, M. C., D. B. Tucker, and A. Lascaux
2000 *Trade Corridors and Ethnic Boundaries.* SWCA Cultural Resource Report No. 98-181. Tucson.

Smith, C. B., J. Runyon, and G. Agogino
1966 A Progress Report on a Pre-Ceramic Site at Rattlesnake Draw, Eastern New Mexico. *Plains Anthropologist* 11:302–313.

Smith, F. J.
1966 The *Relación Diana* of Father Kino. In *Father Kino in Arizona,* by F. J. Smith, J. L. Kessell, and F. J. Fox, pp. 1–52. Arizona Historical Foundation, Phoenix.

Smith, L. D.
1977 Archaeological and Paleoenvironmental Investigations in the Cave Buttes Area North of Phoenix, Arizona. *The Arizona Archaeologist* 11:1–106.

Smith, S. J.

1995 Pollen Analysis of the MTS Canals. In *Archaeology at the Head of the Scottsdale Canal System: Canal and Synthetic Studies*, edited by M. R. Hackbarth, T. K. Henderson, and D. B. Craig, pp. 105–120. Anthropological Papers No. 95-1, Vol. 3. Northland Research, Inc., Flagstaff.

1998 Pollen Analysis. In *The Desert Mountain Properties Archaeological Testing Project, Scottsdale, Arizona*, edited by D. R. Mitchell, pp. 55–67. SWCA Cultural Resource Report No. 98-44. Phoenix.

Snow, D. H.

1991 Upland Prehistoric Maize Agriculture in the Eastern Rio Grande and its Peripheries. In *Farmers, Hunters, and Colonists,* edited by K. A. Spielmann, pp. 71–88. University of Arizona Press, Tucson.

Spicer, E. H.

1962 *Cycles of Conquest: The Impact of Spain, Mexico, and the United States on the Indians of the Southwest, 1533–1960.* University of Arizona Press, Tucson.

Spier, L.

1933 *Yuman Tribes of the Gila River.* University of Chicago Press, Chicago.

*Scattered throughout this classic ethnography is an array of information on Yuman subsistence and land use relevant to prehistoric life in the arid environs of southwestern Arizona.

Spoerl, P. M.

1984 Prehistoric Fortifications in Central Arizona. In *Prehistoric Cultural Development in Central Arizona Archaeology: Archaeology of the Upper New River Region*, edited by P. M. Spoerl and G. J. Gumerman, pp. 261–278. Center for Archaeological Investigations Occasional Paper 5. Southern Illinois University, Carbondale.

Stevens, M. N.

1999 Spectacular Results from Modest Remains. *Archaeology Southwest* 13:4–5.

Stewart, G. R.

1940a Conservation in Pueblo Architecture: I, Primitive Practices. *Scientific Monthly* 51:201–220.

1940b Conservation in Pueblo Architecture: II, Present-day Flood Water Irrigation. *Scientific Monthly* 51:329–340.

Stiger, M.

1979 Mesa Verde Subsistence Patterns from Basketmaker to Pueblo III. *The Kiva* 44:133–144.

Stone, C.

1986 *Deceptive Desolation: Prehistory of the Sonoran Desert in West-Central Arizona.* Cultural Resource Series No. 1. USDI Bureau of Land Management, Phoenix.

1987 *People of the Desert, Canyons. and Pines: Prehistory of the Patayan Country in West Central Arizona.* Cultural Resource Series No. 2. USDI Bureau of Land Management, Phoenix.

1991 *The Linear Oasis: Managing Cultural Resources along the Lower Colorado River.* Cultural Resource Series No. 6. USDI Bureau of Land Management, Phoenix.

Stone, G. D.

1996 *Settlement Ecology: The Social and Spatial Organization of Kofyar Agriculture.* University of Arizona Press, Tucson.

Sullivan, A. P., III

1982 Mogollon Agriculture: An Appraisal and a New Model. *The Kiva* 48: 1–16.

1984 Sinagua Agricultural Strategies and Sunset Crater Vulcanisin. In *Prehistoric Agricultural Strategies in the Southwest,* edited by S. K. Fish and P. R. Fish, pp. 85–100. Anthropological Research Papers, Arizona State University, Tempe.

1986 *Prehistory of the Upper Basin, Coconino County, Arizona.* Archaeological Series No. 167. Arizona State Museum, Tucson.

Swartz, D. L.
1991 *Archaeological Testing at the Romero Ruin.* Technical Report No. 91-2. Center for Desert Archaeology, Tucson.

Tagg, M. D.
1985 *Tonto National Monument: An Archaeological Survey.* Publications in Anthropology No. 31. Western Archeological and Conservation Center, USDI National Park Service, Tucson.

Tarling, D. H.
1983 *Paleomagnetism: Principles and Applications in Geology, Geophysics and Archaeology.* Chapman and Hall, New York.

Teague, L. S., and P. L. Crown (editors)
1984 *Hohokam Archaeology along the Salt-Gila Aqueduct, Central Arizona Project: Synthesis and Conclusions.* Arizona State Museum Archaeological Series No. 150, Vol. 9. University of Arizona, Tucson.

Travis, S.
1990 The Prehistoric Agricultural Landscape of Wupatki National Monument. In *The Wupatki Archaeological Inventory Survey Project,* edited by B. Anderson, pp. 4-1–4-54. Professional Paper No. 35. USDI National Park Service, Southwest Cultural Resources Center, Santa Fe.

*This chapter presents some detailed information regarding water management and non-irrigation agriculture in the Wupatki area. It is one of the few references for the area on these subjects.

Tuggle, H. D., J. Reid, and R. Cole
1984 Fourteenth Century Mogollon Agriculture in the Grasshopper Region of Arizona. In *Prehistoric Agricultural Strategies in the Southwest,* edited by S. K. Fish and P. R. Fish, pp. 101–110. Anthropological Research Papers, Arizona State University, Tempe.

Tuohy, D. R.
1960 Archaeological Survey and Excavation in the Gila River Channel between Earven Dam Site and Buttes Reservoir Site, Arizona. Ms. on file, Arizona State Museum, University of Arizona, Tucson.

Turner, C. L., II, and W. E. Doolittle
1978 The Concept and Measure of Agricultural Intensity. *Professional Geographer* 30:297–301.

Turney, O. S.
1922 *Map of Prehistoric Irrigation Canals.* Map No. 002004. Archaeological Site Records Office, Arizona State Museum, University of Arizona, Tucson.

1924 *Land of the Stone Hoe.* Arizona Republican Print Shop, Phoenix.

1929 Prehistoric Irrigation in Arizona. *Arizona State Historian* 2:2–52; 3:9–45; 4:33–73

Tuthill, C.
1947 *The Tres Alamos Site on the San Pedro River, Southeastern Arizona.* Amerind Foundation Papers No. 4. Dragoon, Arizona.

Updike, J.
1989 *Self-Consciousness: Memories*. Knopf, New York.

Van Gerven, D. P., and S. Guise Sheridan
1994 *The Pueblo Grande Project: The Bioethnography of a Classic Period Hohokam Population.* Publications in Archaeology No. 20, Vol. 6. Soil Systems, Inc., Phoenix.

Van West, C.
1990 *Modelling Prehistoric Climatic Variability and Agricultural Production in Southwestern Colorado: A GIS Approach*. Unpublished Ph. D. dissertation, Washington State University, Pullman.

Van West, C., and J. Altschul
1997 Environmental Variability and Agricultural Economics along the Lower Verde River, A.D. 750–1450. In *Vanishing River, Landscapes and Lives of the Lower Verde River: Overview, Synthesis, and Conclusions,* edited by S. M. Whittlesey, R. S. Ciolek-Torello, and J. H. Altschul, pp. 337–392. SRI Press, Tucson.

Van West, C. R., J. H. Altschul, and J. A. Homburg
1996 Prehistoric Agricultural Productivity along the Lower Verde River. Paper presented at the 61st Annual Meeting of the Society for American Archaeology, New Orleans.

Verosub, K. L.
1977 Depositional and Postdepositional Processes in the Magnetization of Sediments. *Reviews of Geophysics and Space Physics* 15:129–143.

1988 Geomagnetic Secular Variation and the Dating of Quaternary Sediments. *Geological Society of America Special Paper* 227:123–138.

Verosub, K. L., P. J. Mehringer, Jr., and P. Waterstraat
1986 Holocene Secular Variation in Western North America: Paleomagnetic Record from Fish Lake, Harney County, Oregon. *Journal of Geophysical Research* 91:3609–3623.

Vivian, R. G.
1964 Field Notes on the Excavations at Ranch Creek, Southeastern Arizona. Ms. on file, Arizona State Museum, University of Arizona, Tucson.

1974 Conservation and Diversion: Water Control Systems in the Anasazi Southwest. In *Irrigation's Impact on Society,* edited by T. Downing and Mc.G. Gibson, pp. 95–112. Anthropological Papers of the University of Arizona No. 25. Tucson.

*One of the earlier discussions that defines and discusses various prehistoric water-management systems in the Southwest. A useful source of comparative information.

1991 Chacoan Subsistence. In *Chaco and Hohokam: Prehistoric Regional Systems in the American Southwest,* edited by P. L. Crown and W. J. Judge, pp. 57–77. School of American Research Press, Santa Fe.

1992 Chacoan Water Management. In *Anasazi Regional Organization and the Chaco System,* edited by D. E. Doyel, pp. 45–57. Maxwell Museum Papers in Anthropology No. 5. Albuquerque.

Wallace, H. D.
1997 Presence or Parlance? The Meaning of "Hohokam" and Concepts of Culture, A.D. 800 to 1050, in Southeastern Arizona. In *The Archaeology of a Land Between: Regional Dynamics in the Prehistory and History of Southeastern Arizona,* edited by H. D. Wallace. Amerind Foundation, Dragoon, Arizona, and University of New Mexico Press, Albuquerque. In press.

1999 Excavations at the Valencia Site. Technical Report. Center for Desert Archaeology, Tucson. In preparation.

Wallace, H. D. (editor)
1999 *The Archaeology of a Land Between: Regional Dynamics in the Prehistory and History of Southeastern Arizona.* Amerind Foundation, Dragoon, Arizona, and University of New Mexico Press, Albuquerque. In press.

Wallace, H. D., and W. H. Doelle
1997 From Ballcourts to Platform Mounds to Rancherias: A Comparison of Three Organizational Strategies on the Lower San Pedro River. Paper presented at the 62nd Annual Meeting of the Society for American Archaeology, Nashville.

Wallace, H. D., W. H. Doelle, and J. Murray
1999 *An Archaeological Survey of the Lower San Pedro Valley, Arizona, 1990 to 1995.* Technical Report. Center for Desert Archaeology, Tucson. In preparation.

Wallace, H. D., J. D. Heidke, and W. H. Doelle
1995 Hohokam Origins. *Kiva* 60:575–618.

Warburton, M., and D. Graves
1992 Navajo Springs, Arizona: Frontier Outlier or Autonomous Great House? *Journal of Field Archaeology* 19:51–74.

Ward, A. (editor)
1978 *Limited Occupation and Activity Sites: A Collection of Conference Papers.* Contributions to Anthropological Studies No. 1. Center for Anthropological Studies, Albuquerque.

Wasley, W. W., and A. E. Johnson
1965 *Salvage Archaeology in Painted Rocks Reservoir, Western Arizona.* Anthropological Papers No. 9. University of Arizona Press, Tucson.

Waters, M. R.
1982a The Lowland Patayan Ceramic Tradition. In *Hohokam and Patayan: Prehistory of Southwestern Arizona,* edited by R. H. McGuire and M. B. Schiffer, pp. 275–297. Academic Press, New York.

1982b The Lowland Patayan Ceramic Typology. In *Hohokam and Patayan: Prehistory of Southwestern Arizona,* edited by R. H. McGuire and M. B. Schiffer, pp. 537–580. Academic Press, New York.

1986 *The Geoarchaeology of Whitewater Draw, Arizona.* Anthropological Papers No. 45. University of Arizona, Tucson.

1988 Holocene Alluvial Geology and the Geoarchaeology of AZ BB:13:14 and the San Xavier Reach of the Santa Cruz River, Arizona. *Geological Society ofArizona Bulletin* 100:479–491.

1992 *Principles of Geoarchaeology: A North American Perspective.* University of Arizona Press, Tucson.

1996 *Surficial Geologic Map of the Gila River Indian Community.* P-MIP Technical Report No. 96-1. Cultural Resource Management Program, Gila River Indian Community, Sacaton.

1998 The Effect of Landscape and Hydrologic Variables on the Prehistoric Salado: Geoarchaeological Investigations in the Tonto Basin, Arizona. *Geoarchaeology: An International Journal* 13:105–160.

Waters, M. R., and J. Field
1986 Geomorphic Analysis of Hohokam Settlement Patterns on Alluvial Fans along the Western Flank of the Tortolita Mountains, Arizona. *Geoarchaeology: An International Journal* 1:324–345.

Waters, M. R., and J. C. Ravesloot

2000 Late Quaternary Geology of the Middle Gila River, Gila River Indian Reservation, Arizona. *Quaternary Research* 54:49–57.

2001 Landscape Change and the Cultural Evolution of the Hohokam along the Middle Gila River and Other River Valleys in South-Central Arizona. *American Antiquity* 66:285–299.

Waters, M. R., and A. I. Woosley

1990 The Geoarchaeology and Preceramic Prehistory of the Willcox Basin, SE Arizona. *Journal of Field Archaeology* 17:163–175.

Weaver, D. E., Jr.

1984 *A Research Design for the Gatlin Site National Historic Landmark (NA 17, 994), Gila Bend, Arizona.* Museum of Northern Arizona, Flagstaff.

Weed, C. S., and A. E. Ward

1970 The Henderson Site: Colonial Hohokam in North Central Arizona, a Preliminary Report. *The Kiva* 6:1–12.

Wells, W. E.

1971 Prehistoric Settlement Patterns of Lower Cherry Creek. Ms. on file, Department of Anthropology, Arizona State University, Tempe.

Wheat, J. B.

1952 Prehistoric Water Sources of the Point of Pines Area. *American Antiquity* 17:3:185–196.

*One of the early and classic studies of water management in prehistoric eastern Arizona.

1955 *Mogollon Culture prior to A.D. 1000.* Memoirs of the Society for American Archaeology No. 10. Menasha, Wisconsin.

Whittlesey, S. M.

1995 Mogollon, Hohokam, and O'otam: Rethinking the Early Formative Period in Southern Arizona. *Kiva* 60:465–480.

1998 Rethinking the Core-Periphery Model of the Pre-Classic Period Hohokam. In *Vanishing River, Landscapes and Lives of the Lower Verde Valley: The Lower Verde Archaeological Project,* edited by S. M Whittlesey, R. S. Ciolek-Torrello, and J. H. Altschul, pp. 597–628. SRI Press, Tucson.

Whittlesey, S. M., and S. Benaron

1998 Yavapai and Western Apache Ethnohistory and Material Culture. In *Vanishing River, Landscapes and Lives of the Lower Verde Valley: The Lower Verde Archaeological Project,* edited by S. M Whittlesey, R. S. Ciolek-Torrello, and J. H. Altschul, pp. 143–183. SRI Press, Tucson.

Whittlesey, S. M., and R. S. Ciolek-Torrello

1992 A Revolt against Rampant Elites: Toward an Alternative Paradigm. In *Proceedings of the Second Salado Conference, Globe, Arizona,* edited by R. C. Lange and S. Germick, pp. 312–324. Occasional Paper No.1992. Arizona Archaeological Society, Phoenix.

Whittlesey, S. M., R. S. Ciolek-Torrello, and J. H. Altschul (editors)

1997 *Vanishing River, Landscapes and Lives of the Lower Verde Valley: The Lower Verde Archaeological Project.* Statistical Research Technical Series, Tucson.

Whittlesey, S. M., W. L. Deaver, and J. J. Reid

1998a Yavapai and Western Apache Archaeology of Central Arizona. In *Vanishing River, Landscapes and Lives of the Lower Verde Valley: The Lower Verde Archaeological Project,* edited by S. M Whittlesey, R. S. Ciolek-Torrello, and J. H. Altschul, pp. 185–214. SRI Press, Tucson.

Whittlesey, S. M., T. Majewski, J. R. Welch, M. C. Bischoff, and R. Ciolek-Torrello

1998 Euroamerican History, 1540 to the Present. In *Vanishing River, Landscapes and Lives of the Lower Verde Valley: The Lower Verde Archaeological Project,* edited by S. M Whittlesey, R. S. Ciolek-Torrello, and J. H. Altschul, pp. 281–336. SRI Press, Tucson.

Wilcox, D. R.

1978 The Theoretical Significance of Field Houses. In *Limited Occupation and Activity Sites,* edited by A. Ward, pp. 25–34. Contributions to Anthropological Studies No. 1. Center for Anthropological Studies, Albuquerque.

1979 The Hohokam Regional System. In *An Archaeological Test of the Sites in the Gila Butte–Santan Region, South-Central Arizona,* edited by G. Rice, D. Wilcox, K. Rafferty, and J. Schoenwetter, pp. 77–116. Anthropological Research Papers No. 18. Arizona State University, Tempe.

1986 Interim Report: Excavations of Three Sites on Bottomless Pits Mesa, Flagstaff, Arizona. Ms. On file, Statistical Research, Inc., Tucson.

1991 Hohokam Social Complexity. In *Chaco and Hohokam: Prehistoric Regional Systems in the American Southwest,* edited by P. L. Crown and W. J. Judge, pp. 253–275. School of American Research Press, Santa Fe.

Wilcox, D. R., and W. B. Masse (editors)

1981 *The Protohistoric Period in the North American Southwest, A.D. 1450–1700.* Anthropological Research Papers No. 24. Department of Anthropology, Arizona State University, Tempe.

Wilcox, D. R., T. R. McGuire, and C. Sternberg

1981 *Snaketown Revisited.* Archaeological Series No. 155. Arizona State Museum, University of Arizona, Tucson.

Wilcox, D. R., and L. O. Shenk

1977 *The Architecture of the Casa Grande and Its Interpretation.* Archaeological Series No. 115. Arizona State Museum, University of Arizona, Tucson.

Wilcox, D., and C. Sternberg

1983 *Hohokam Ballcourts and Their Interpretation.* Arizona State Museum Archaeological Series No. 160. Tucson.

Wills, W. K.

1988 *Early Prehistoric Agriculture in the American Southwest.* School of American Research Press, Santa Fe.

1990 Cultivating Ideas: The Changing Intellectual History of the Introduction of Agriculture in the American Southwest. In *Perspectives on Southwestern Prehistory,* edited by P. Minnis and C. Redman, pp. 319–322. Westview Press, Boulder.

1992 Plant Cultivation and the Evolution of Risk-Prone Economies in the Prehistoric American Southwest. In *Transitions to Agriculture in Prehistory,* edited by A. Gebauer and T. D. Price, pp. 153–176. Prehistory Press, Madison.

Wills, W. K., and B. B. Huckell

1994 Economic Implications of Changing Land-use Patterns in the Late Archaic. In *Themes in Southwest Prehistory,* edited by G. J. Gumerman, pp. 33–52. School of American Research Press, Santa Fe.

Wilson, J. P.

1999 Peoples of the Middle Gila: A Documentary History of the Pimas and Maricopas, 1500s–1945. Ms. on file, Cultural Resource Management Program, Gila River Indian Community, Sacaton.

Wilson, J. S.

1990 We've Got Thousands of These: What Makes an [sic] Historic Farmstead Significant. *Historical Archaeology* 24:23–33.

Winter, J. C.

1973 Cultural Modifications of the Gila Pima: A.D. 1697–1846. *Ethnohistory* 20:65–77.

1978 Anasazi Agriculture at Hovenweep. In *Limited Activity and Occupation Sites,* edited by A. Ward, pp. 83–97. Contributions to Anthropological Studies No. 1. Center for Anthropological Studies, Albuquerque.

Withers, A. M.

1973 *Excavations at Vaishni Village, Arizona,* edited by W. T. Duering. *The Arizona Archaeologist* No. 7. Arizona Archaeological Society, Phoenix.

Wittfogel, K.A.

1957 *Oriental Despotism.* Yale University Press, New Haven.

Wöcherl, H., and J. J. Clark

1997 The Square Hearth Site, AZ AA: 12:745(ASM). In *Archaeological Investigations of Early Village Sites in the Middle Santa Cruz Valley: Descriptions of the Santa Cruz Bend, Square Hearth, Stone Pipe, and Canal Sites,* by J. B. Mabry, D. L. Swartz, H. Wöcherl, J. J. Clark, G. H. Archer, and M. W. Lindeman, pp. 229–280. Anthropological Papers No. 18. Center for Desert Archaeology, Tucson.

Wood, J. S.

1986 Vale of Tiers: Tonto Basin in the 14th Century. Paper presented at the 56th Pecos Conference, Payson, Arizona.

1992 Toward a New Definition of Salado: Comments and Discussion on the Second Salado Conference. In *Proceedings of the Second Salado Conference, Globe, Arizona,* edited by R. C. Lange and S. Germick, pp. 337–344. Occasional Paper No. 1992. Arizona Archaeological Society, Phoenix.

Wood, J. S., and M. McAllister

1984 Second Foundation: Settlement Patterns and Agriculture in the Northeastern Hohokam Periphery. In *Prehistoric Agricultural Strategies in the Southwest,* edited by S. K. Fish and P. R. Fish, pp. 271–291. Anthropological Research Papers, Arizona State University, Tempe.

Woodbury, R. B.

1960 The Hohokam Canals at Pueblo Grande, Arizona. *American Antiquity* 26:267–270.

1961a *Prehistoric Agriculture at Point of Pines, Arizona.* Memoirs of the Society for American Archaeology No. 17. Salt Lake City.

1961b A Reappraisal of Hohokam Irrigation. *American Anthropologist* 63:550–560.

*This classic study of prehistoric agricultural technologies in the Point of Pines area remains a primary and important reference.

Woodbury, R. B., and E. Zubrow

1979 Agricultural Beginnings: 2000 B.C.–A.D. 500. In *Southwest*, edited by A. Ortiz, pp. 22–30. Handbook of North American Indians, vol. 9, W. C. Sturtevant, general editor. Smithsonian Institution, Washington, D.C.

Woodson, M. K.

1999 Migrations in Late Anasazi Prehistory: The Evidence from the Goat Hill Site. *Kiva* 65:63–84.

2002 *A Research Design for the Study of Prehistoric and Historical-Period Irrigation Systems in the Middle Gila Valley, Arizona.* P-MIP Technical Report No. 2002-01. Cultural Resource Management Program, Gila River Indian Community, Sacaton.

Woodson, M. K., and E. Davis

2001 *A Cultural Resources Assessment of the Western Half of the Blackwater Management Area, Pima-Maricopa Irrigation Project, Gila River Indian Community, Pinal County, Arizona.* P-MIP Technical Report No. 14. Cultural Resource Management Program, Gila River Indian Community, Sacaton.

Woodson, M. K., and D. P. Morgan

2001 *A Preliminary Report on the Results of a Phase II Data Recovery Program Conducted in the Sweetwater Site (GR-931) along State Route 587, Gila River Indian Community, Pinal County, Arizona.* CRMP Technical Report No. 2001-21. Cultural Resource Management Program, Gila River Indian Community, Sacaton.

Woodson, M. K., and R. B. Neily

1998 *Cultural Resource Testing along the Pecos Road Segment of the Pecos–Price Canal Alignment, Santan Extension (Memorial) Management Area, Pima-Maricopa Irrigation Project, Gila River Indian Community, Maricopa County, Arizona.* P-MIP Technical Report No. 97-08. Cultural Resource Management Program, Gila River Indian Community, Sacaton

Woodson, M. K., R. B. Neily, and J. C. Ravesloot

1999 The Archaeology of the Gila River Landscape. Paper presented at the 72nd Pecos Conference, Pinedale, Arizona.

Woodson, M. K., and B. G. Randolph

2000 *National Register of Historic Places Eligibility Assessment of 67 Sites in the Blackwater Management Area, Pima-Maricopa Irrigation Project, Gila River Indian Community, Pinal County, Arizona.* P-MIP Technical Report No. 00-03. Cultural Resource Management Program, Gila River Indian Community, Sacaton

Woosley, A.

1980 Agricultural Diversity in the Prehistoric Southwest. *The Kiva* 45:317–337.

Zimmerman, J. D.

1966 *Irrigation.* McGraw-Hill, New York.