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Recent studies (e.g., Clark 2002; Doolittle and Neely 2004a; Neely 2001) have disclosed several forms of agricultural technology and methodology employed by the prehistoric occupants of the Safford Valley. This paper is devoted to the consideration of another: foothill or bajad*a* agriculture as it appears in Lefthand Canyon. This system incorporated the use of canals, some of which were rock-bordered, to convey waters from springs, rainfall and snowmelt runoff from the mountains to agricultural gardens and fields, some of which were rock-bordered or rock-terraced, and associated habitation sites. Reservoirs and direct precipitation dry-farmed fields were also incorporated. The foothill systems of the Safford Valley appear to constitute some of the best preserved complex water management systems in the American Southwest.

The agricultural system in Lefthand Canyon (Figure 1, Locus 3) is one of the most throughly studied locations in the Safford Valley. It has been found to provide excellent undisturbed preservation, substantial time-depth, unusual variety and complexity, and well-defined association with habitation and activity sites. These characteristics provide an unique opportunity to study an agricultural system superbly adapted to the available resources and to gain insights into the interrelated economic, socio-political, and religious systems. Survey has shown Lefthand Canyon to be the locus of one of at least

seven similar water management and irrigation systems located in the northern foothills (bajada) of the Pinaleño Mountains on the south side of the Safford Valley (Figure 1). Although this paper focuses on Lefthand Canyon, findings in other parts of the Safford Valley and elsewhere will be mentioned to put the foothill system into perspective.

Historical Background

The first published reference to the foothill water management and irrigation features and systems of the Safford Valley was by Adoph F. Bandelier (1892). Subsequent investigators (e.g., Fewkes 1904; Hough 1907; Russell 1908; Sauer and Brand 1930; Stewart 1939, 1940a, b; Touhy 1960; Woodbury 1959) have also noted the presence of aspects of agricultural technology in the valley. However, few devoted much time to their study and none recognized the extent and complexity of the systems. My research on these systems began in 1994 when I fortuitously found the Lefthand Canyon system while visiting excavations at the Goat Hill site (Woodson 1995, 1999). Several sessions of fieldwork followed in which I was aided by S. Christopher Caran, Joseph S. Crary, William E. Doolittle, Jerry Howard and members of his "SWAT" team, Everett J. Murphy, Lee Dewester, J. Wesley Jernigan, Jennifer R. Rinker, Sharon F. Urban, Samuel M. Wilson, and students from the Anthropology Department, University of Texas at Austin.

Environmental Setting

Lefthand Canyon is located near the western end of the Safford Valley. The survey area for this study encompasses about 10^2 kilometers in the northern foothills of the Pinaleño Mountains (Figure 1, Locus 3). The area is within the Basin and Range Physiographic Zone of Arizona (Wilson 1962: Figure 13), and is situated on a remnant

terrace. Lefthand Canyon drainage courses in a south-to-north direction through the center of the survey area. The survey area ranges in elevation from approximately 1,158 (3,800 feet) meters to about 960 meters (3,150 feet) where Lefthand Canyon joins Cottonwood Wash. It is in the Chihuahuan Desert subdivision of the Lower Sonoran Life-zone (Lowe 1964: 15-20), with a Southwestern Desertscrub type biotic/vegetation community. The creosotebush biotic community dominates (Lowe 1964: 20-24). A riparian association characterizes Lefthand Canyon (Lowe 1964: 60-63). Warm temperatures allow a growing season that averages between 200 to 250 days in length (Bronitsky and Merritt 1986:21; Sellers and Hill 1974:422). The valley averages about 25.4 centimeters (10 inches) of precipitation annually (Sellers and Hill 1974: 7-8), but almost half falls during the months of July and August. The evapo-transpiration rate for the area is over nine times greater than the rainfall.

The Lefthand Canyon System

The Lefthand Canyon settlement and agricultural system extends in a linear fashion for a distance of nearly five kilometers along both sides of the intermittent, at times perrenial, drainage. However, a closer inspection of these systems reveals that there are significant differences that divide them into two linear segments. About a third of the way down the canyon (Figure 2) the system takes on a new aspect; one that is characterized by several canals that do not connect with the up-stream (southern) canals and by the presence of a greater number of habitation sites. Several of these sites date earlier than the Goat Hill site and all present very different site plans and settlement pattern. A description of the two segments follows, and the significance of the differences are considered.

The Southern Segment of the Canyon

The southern segment of Lefthand Canyon is distinguished by three prominent features: a) the Goat Hill site (AZ.CC:1:28 [ASM]), b) the canal and terrace system that trends down the east side of the canyon, and c) the offtake of a canal that courses immediately west of the canyon.

The Goat Hill Site (AZ.CC:1:28 [ASM]). This is the only habitation site found in this segment of the canyon. This site is thusfar unique in the Safford Valley, although it is suspected that similar sites may be present in areas not yet well surveyed. This 35 room masonry pueblo, situated atop an artificially leveled butte, has a central plaza and a D-shaped kiva. It was constructed and occupied during the Classic period from about A.D. 1275 to 1325. The construction of this site has been attributed to northeastern Arizona Kayenta-Tusayan immigants into the Safford Valley (Woodson 1995, 1999).

Canals, Gardens, and Fields on the East Side of the Canyon. About 250 meters to the west-northwest of the Goat Hill site lies the offtake of the primary canal that supplied water to irrigate a linear system of agricultural fields on the east side of the canyon. The majority of the canals and smaller ditches found in this segment of the canyon (Figures 3, 4, and 5) were rock-bordered, and several small test excavations indicated that most were probably rock-lined as well. Linear borders and grids of rock, as well as rock-faced terraces, defined "improved" irrigated agricultural fields and gardens. These improved canals, fields, and gardens reflect a high energy cost and investment.

In addition, a few areas that were devoid of linear borders of rock and rock-faced terraces were tentatively listed as "unimproved" fields and gardens on the basis of their

topography, associated artifacts, and locations in relation to canals and site. The majority of these gardens and fields appear to have been irrigated.

The Canals. In this segment of Lefthand Canyon the drainage channel has cut deeply and there is currently no perceptible floodplain present. The canal system begins as a small, shallow, broadly U-shaped channel in the earth that branches from a cutbank on the east side of Lefthand Canyon at about 3.5 meters above the present floor of the canyon. This channel courses down slope for some 50 meters and then becomes more clearly visible as two closely spaced parallel alignments of unshaped slabs, cobbles, and small boulders of local rock (Figure 4). In places these alignments are clearly discernible; in others they are not. The course of the channel, which averages about 65 cm in width, is seen to be rather sinuous; perhaps to better follow the lay of the land and maintain a channel grade of approximately 1.5 to 2%. Occasionally, an alignment of cobbles was constructed at right-angles across the canal channel, but only obstructing the lower part of the channel. These partial blockages of the channel may have acted to slow water flow (cf. Lindsay 1961:183-184), but often mark the presence of canal offtakes. The use of rock to border one or both of the walls of the canals is functional. As found in other areas (e.g., Fish and Fish 1984:Figure 4; Lindsay 1961), it provides channel wall stability in the loose, sandy soils characterizing the area. Most of the earth-walled canals have segments of their courses rock-bordered in locations where the soils are either particularly loose and sandy or in places where a washout of the canal walls was likely.

The canal continued northward down the terrace along the tops of several finger-like ridges. The canal branches into several rock-bordered, slightly smaller, secondary and tertiary canals/ditches as it courses down-slope. Water could be turned out from the

primary canal directly into gardens and fields through small sluices or gates in the canal walls, or into the smaller ditches that branch from the canal. A total of nearly 1,230 meters of canals and ditches was mapped in this system. The primary canals in this system were about 1,050 meters in length (Figure 3). The remaining canals/ditches mapped, totaling approximately 180 meters, represent the secondary and tertiary branchings extending to the fields from the primary canal.

Gardens and Fields. Following definitions found in the literature (e.g., Doolittle 2000:82-85), and based primarily on size and proximity to habitation sites, it is evident that both gardens and fields were present and canal irrigated. Both "improved" gardens and fields (those with rock constructions such as linear borders, grids, terrace walls, and check dams) and "unimproved" gardens and fields (those lacking any rock improvements) are present in the southern canyon segment.

"Improved" Gardens and Fields. About 100 meters north of the primary canal offtake from the Lefthand Canyon drainage, a section of the primary canal and associated features that formed a complex garden was chosen for more detailed mapping (Figure 5). This area, is similar to the small irrigated gardens at Hopi (Maxwell and Anschuetz 1992:Figure 3.2). The larger rock-bordered garden "plots" are clearly discernable and range from about 4.5 m^2 to 40.5 m^2 in area, with an average area of about 15.9 m^2. Downslope, north of this detail mapping area, the rock-bordered and terraced areas increase in size and become fields, with a maximum size of about 18 by 20 meters (360 m^2 in area). Small turn-out sluices or "gates" were found in the alignments of rocks bordering the canal. These gates would allow controlled amounts of water to be diverted from the main canal channel into smaller canals, directly into garden and field areas, and

into smaller stone-bordered areas, that, for want of a better term, I have called "planters." The patterning of the gates was such that they were present most frequently at the up-slope corner of an adjacent plot or planter. These gates could be easily closed or opened by the insertion or removal of rocks and mud.

The "planters" illustrated in Figure 5 consist of rock-bordered areas that vary in form and range in area from approximately 0.7 m^2 to 4.2 m^2. They occur adjacent to rock-bordered canals and smaller offtake ditches. In many, but not all, cases they were connected with rock-bordered canals or ditches by a "gate." Their use was most likely as smaller irrigated garden areas. These are similar to the planting "basins" recorded in the gardens at Hopi (Hack 1942:36-37; Maxwell and Anschuetz 1992:Figure 3.2) and the "waffle" gardens at Zuni (Bohrer 1960; Doolittle 2000:97-98; Forde 1931; Stewart 1940b).

It seems possible that some of these features, the ones without a gate, may have been designed to hold water. In such a case, the empounding of a small amount of water, when the canal was dry or being used for other purposes, could have served to provide a source from which the agriculturalist could dip, with a gourd or a small ceramic vessel, to apply water directly to the base of wilting plants. This form of labor-intensive hand-watering has been documented ethnographically in the American Southwest among the Zuni (Doolittle 2000:98; Ladd 1979:497, Figure 12) and the Akimel O'odham (Castetter and Bell 1942:160), as well as in the Valley of Oaxaca in southern Mexico (Kirkby 1973:117-119) and in Guatemala (Wilken 1987:178-193). Prehistoric use of hand watering has been suggested for the Tonto Basin (Welch 1994:106) and the Valley of Oaxaca (Neely et al. 1990:146-150). There are about 50 of these planters present in this segment of the canyon.

The precise use of this and other gardens by the prehistoric inhabitants remains speculative. However, in addition to the generally accepted proposals that the gardens were used for growing herbs and exotic plants for domestic and religions uses, it is feasable that they may also have been used to foster the growth of well-tended, hardy seedlings to be transplanted.

As with gravel-mulched fields (Maxwell and Anschuetz 1992:65-66), the maximum use of rock in the construction of these gardens may have increased the temperature of the garden plots and planters, thereby accelerating seed gemination and plant development. This heat storage may also have garded against early frost damage and lengthened the growing season by protecting against late frosts.

Further down canyon (north) from the gardens, and interspaced between some of the ditch-bearing finger-like ridges of the canyon's terraced surface, are what appear to be erosional channels. These channels, some relatively narrow and deep and some quite broad and shallow, have been cleared of rocks. The rocks had apparently been thrown to either side of the channels and also used to modify the channel into a series of leveled areas that proceed in a stair-step fashion down slope (Figures 6 and 7). This had been accomplished through the construction of dry-laid linear borders and terrace walls of unmodified cobbles and boulders at nearly right-angles to the channel of the drainage to form a series of adjacent "improved" fields. Varying from one to at least five rocks in height, there are at least 170 borders and terraces present in this system. These provided approximately 40,000 m^2 of field area for cultivation.

One set of 96 mapped rock-faced terraces was found to extend about 575 meters. However, side channels diverging from and joining the terrace system were also seen to

have terrace walls; adding about 100 meters to the complex. The terraced areas (the effective area of cultivation) comprising the southernmost 22 fields in this complex (Figure 6) extend about 473 meters in length, range from about 12 m^2 to nearly 124 m^2 in area, have an average field area of nearly 55 m^2, and provide a total cultivable field area of about 1,200 m^2 (about 0.12 hectar).

Thirty-five of the terrace walls in this complex (12 are shown in Figure 6) were found to have a small cobble-filled or cobble-outlined area located down-slope from, and immediately in front of, the lowest portion of the wall (Figures 6, 8, 9, and 10). These features may have served as a type of "splash-pad" to prevent the erosion produced by water flowing over the terrace wall onto the terrace below. Excavation will be necessary to determine if the small earth-filled rectilinear or curvilinear areas bordered by rocks may have formed a small pool that served a similar function and possibly also produced a type of “seepage” field (Hack 1942:34).

Christopher Caran, a professional geologist specializing in Holocene geomorphology and hydrology, examined these field areas. Caran noted that a great deal of human effort was expended over the entire surface of the terrace to remove the naturally occurring cobbles and boulders from the field areas, transport them to the areas bordering the fields, and to construct the terracing walls. In addition, Caran’s examination disclosed a rather surprising observation. This well-preserved stone-faced terraced field system suggested to him that the entire channel, which was initially assumed to be a natural erosional feature, was largely a product of landscape modification by the agriculturalists. In addition to systematically removing the rocks, he considers it probable that humans, rather than natural erosional processes, produced the channel in which the terraces were

constructed. He also observed that the sandy soils forming the fields in this channel might have been purposely brought in from elsewhere to provide a choice growing environment for whatever was cultivated therein.

Large rock-bordered features formed the down-slope end of many of the canals and ditches (Figure 3). These features, circular in form and ranging in size from about 3 meters to around 8 meters in diameter, appear to be analogous to the O'odham tail-water gardens or "second gardens" (Crosswhite 1981:64; Rea 1979; Welch 1994:108, Table 5.4). A variation on this theme, employing rock-bordered grids at the terminus of rock diversion walls, has been reported by Rogers (1970) for the Upper Little Colorado region southeast of Young, Arizona. In Lefthand Canyon, most of these canal terminus gardens currently contain large mesquite trees. It seems probable that these rock-bordered areas were used as "planters" for mesquite trees and other plants to supplement the diet.

Cresent-shaped and circular features, usually constructed of boulders and ranging from about one to five meters in diameter and one to three courses high, were found in both irrigated and dry-farmed fields. The crescents are oriented with their open end facing up-slope, were probably yet another form of water and soil catchment feature, and were found in both improved and unimproved fields. Circular features were found attached or adjacent to canals, but others occurred isolated in field areas. Like the rock-bordered features discussed immediately above, these crescents and circles of rock also are frequently found to have mesquite trees growing in them. These features have also been found in the Upper Little Colorado region southeast of Young, Arizona (Rodgers 1970).

Non-irrigated improved fields were found in several locations in this segment of the canyon. Perhaps the best example was found in the small intermittent drainage that

begins at the toe and northern edge of Goat Hill butte and courses around the east side of the butte. In this drainage the agriculturalists construced a series of about 40 dry-laid rock checkdams and rock-faced terraces, ranging from about two to 15 meters in length and from one to five courses in height, at right-angles to the channel. In addition, several linear borders of rock, ranging from about 10 to 40 meters in length and one course high, were constructed along the up-slope side of the drainage, following the contours of the land and paralleling the channel.

"Unimproved" Fields. Although most of the fields found in the southern segment of the canyon were found to be "improved" a few level areas probably served as "unimproved" fields. While some fields of this type were identifiable due to the presence of offtakes from rock-bordered canals leading past these areas, the absence of the rock water management features and thinner sherd scatters made determination of their shapes and sizes hightly speculative. Even more acute difficulties occurred in the identification of fields that received their moisture directly from precipitation.

The Canal Immediately West of the Canyon. A cleverly designed canal has its offtake about 450 meters to the southwest of the Goat Hill Site (Figure 2). This canal carries water from Lefthand Canyon about 650 meters to the northwest where it intersects a natural drainage coursing northward from the upper foothills of the Pinaleño Mountains. From this point of intersection the canal carries both the water from Lefthand Canyon and runoff from the natural drainage. From the offtake northward, the channel exhibits modifications such as the placement of dam-like constructions across the channel and the rock armoring of cutbank areas as it progresses northward to empty into Lamb Tank. Another human-modified drainage flows from Lamb Tank and courses northeast

to drain into the lower reaches of Lefthand Canyon. The total length of this canal is about 4,450 meters. Improved and unimproved agricultural fields border both sides of this canal.

Reservoirs. Ceramics found in the vicinity of Lamb Tank, and other tanks along the north face of the Pinaleño Mountains in the Safford Valley, suggests the use of reservoirs as part of foothill canal irrigation agriculture ocurred during the time of deteriorating climatic conditions at the end of the Late Formative and beginning of the Early Classic periods (Rose 1994:357-358; Van West and Altschul 1994:400-403). Prehistoric wells and reservoirs are found elsewhere in the Southwest, dating from ca. 10,000 BP to A.D. 1400 (e.g., Draper 2004; Evens 1951; Wheat 1951). While this type of feature is traditionally thought of as a domestic water resource, it may have also served for irrigation. Surveys (Neely 1995a; Neely and Crary 1998) suggest that at least some of these reservoirs were originally natural marshes or *ciénegas* (see Doolittle 1997) that were modified to become larger water impoundment areas. These impoundments evidently functioned as did the Papago reservoirs recorded in southern Arizona and northwestern Sonora by Castetter and Bell (1942) and in Iran by Bonine (1982). Castetter and Bell (1942:169-170) describe the Desert Papago *balsa* as an embanked reservoir, from which the water is allowed to enter a ditch through a gate into a cultivated field. They state that it is possible to raise a crop from the water of a single filling of the *balsa*. Bonine (1982:154) reports that such pond-like features, called *estakhr sarkh* and functioning in Central Iran in both ancient and modern times, serve villages when water is not present in sufficient flow or quantity for agricultural irrigation. The water is impounded and collected until enough is present for irrigation; then it is drained by canals

taking the water to the fields to complete the irrigation process. The two examples noted above illustrate the precise procedure observed currently conducted with Lebanon Reservoirs #1 and #2, just south of the city of Safford. It is probable that the modern Lebanon Reservoirs are also refurbished and enlarged prehistoric reservoirs.

The Northern Segment of the Canyon

The Sites. The sites in the northern portion of Lefthand canyon (Figure 2) are more numerous, have a greater length of occupation, have a different site layout (plan), and a different settlement pattern than found in the southern segment of the canyon. A total of 18 habitation sites, and several activity sites (e.g., roasting pits, bedrock metates and mortars), have been recorded by survey. Of the 18 habitation sites, five (AZ.CC:1:11, 43, 52, 53, and 56 [ASM]) have been subjected to professional test excavations (Jernigan, personal communication, 1997; Rinker 1998; Rinker and Neely 1998), but all have had varying amounts of looting. Seventeen of these sites are relatively small, consisting of an estimated two to twenty pithouses, pitrooms, and/or masonry surface rooms, depending on their period(s) of occupation. These sites range in area from about 4.5m^2 for a field house to about 5,800 m^2 for a pithouse village. The Spear Ranch Site (AZ.CC:1:11 [ASM]) is in a separate category as the largest site in the entire canyon; estimated to have had about a hundred rooms and an estimated area of about 10,000 m^2. The ten sites on the west side of the drainage and eight on the east form a continuous line of habitations paralleling the course of the drainage. Most were located on the first terrace above the flood plain; providing a secure location from floods while giving close access to water and the irrigated gardens and fields. The sites were recorded as separate sites, and assigned 18 individual ASM numbers. However, their juxtaposition would suggest that

they probably should be considered as one large site; or possibly two, with each side of the Lefthand Canyon drainage forming a separate linear settlement pattern.

The Canals. The primary canals on both sides of the drainage have offtakes that are clearly separate from the canals in the south canyon segment. These are primarily earth-walled canals, but large portions of their channels were bordered with rock. The total length of all of the canals recorded in this canyon segment is between about 8,000 and 12,100 meters. Canals were constructed to supply water to fields located in three distinct locations: the floodplain of the canyon, the first terrace above the floodplain, and the higher terraces. In addition to supplying water for the agricultural fields, it is evident that the canals also supplied water for domestic purposes and household gardens.

Canals on the West Side of the Canyon. One primary canal with several branches was recorded on the west side of the canyon (Figure 2). Canal grade on the west side ranges from about 1.2% to about 1.8% (Rinker 1998). A study of the canal fill indicates that the canal was well designed and evidently functioned efficiently (Caran, personal communication, 1997). A late 19th/ early 20th century re-excavation of the northern-most portion of this canal (Ross Bryce, personal communication, 1997) increased the grade to about 2.5% and resulted in a rapid flow and rapid sedimentation (Caran, personal communication, 1997).

The total traceable length of the canals mapped on the west side of the lower canyon is about 5,396 meters. Except for a few relatively short areas, where erosion or alluviation has occurred to obliterate or hide the channel, this canal is clearly visible. It offtook water from the west side of the drainage of Lefthand Canyon at an elevation of about 1,060 meters (about 3,480 feet), it then courses along the first terrace above the

floodplain to ultimately terminate by emptying back into the drainage of Lefthand Canyon at an elevation of approximately 978 meters (about 3210 feet). This canal had a shallow U-shaped cross-section that ranged from about 30 centimeters to 1.0 meter in width, and averaged about 50 - 60 centimeters wide at ground level. In places, a low-mounded spoil bank is visible to one or both sides of the channel. In several locations, including the floodplain of Lefthand Canyon, sections of the channel are clearly rock-bordered. This canal system apparently functioned to provide waters to agricultural fields for irrigation purposes as well as to habitation sites situated along its course for domestic uses and gardens.

At a point about 510 meters from its point of origin, a ditch from a higher terrace to the northwest joins this canal (Figure 2). This ditch is clearly visible for the 175 meters it courses along the side of the higher terrace up to the top, where it branches west and north and is traceable for another 30 meters before it fades from view. This side channel is thought to function to augment the canal's water flow with runoff from the catchment area of the higher terrace.

Almost immediately after its offtake from the drainage, the primary canal had small offtakes to the east that supplied water to rock-bordered fields on the floodplain and the first terrace. About 700 meters from its head the canal exhibits major branchings. The primary canal continues its course at the rear of the first terrace, at the toe of the second terrace, to supply water to habitations, gardens, as well as improved and unimproved fields on the first terrace. One set of branchings turn west to water mostly unimproved fields on the upper terraces while another set of branchings turn east to water improved and unimproved fields on the floodplain.

Ceramics and flaked stone artifacts were found along the primary canal, and the density of the artifact scatter increased in the vicinity of habitation sites. Agricultural fields adjacent to this canal also had a relatively dense surface scatter of ceramic and lithic materials. A large number of fragmentary grinding stone artifacts (i.e., manos, metates, mortars, and pestles) were found along both sides (but mostly on the east side) of the canal channel from a point about half way down the canal to where it terminates. Thirty-seven fragments of grinding stones were found along this 1,100 meter long segment of the canal. E. J. Murphy (Safford Archaeological Site Steward) commented that about ten complete and nearly complete grinding stones that he had seen along this canal in the early 1990s were now missing; presumably removed by local collectors.

Canals on the East Side of the Canyon. At least one primary canal, with several branches, was clearly visible on the east side of the canyon. This canal was constructed to course west of the habitations sites and along the edge of the first terrace above the floodplain. The total length of this canal is approximately 2,607 meters. However, there is some evidence that a branch of this canal was constructed to course at the toe of the second terrace above the floodplain, to the east of the habitations sites (Figure 2). Like the canal supplying Lamb Tank, this canal appears to have utilized a natural drainage channel for part of its course. It is about 4,142 meters in length, but has been indicated by a dashed line on Figure 2 because of its lack of definition. If the latter feature were a canal, this would modify the total canal length for the east side of the drainage in this segment of the canyon to about 6,750 meters.

Irrigated Fields and Gardens. The fields and gardens in this segment of the canyon also have a linear distribution down-slope, paralleling the drainage. In contrast with the

southern segment of the canyon, the northern fields and gardens were more difficult to distinguish because they had fewer improvements (i.e., rock linear borders, terrace walls, etc). However, many of these fields were recognizable in survey, especially on the west side of the canyon, because of well-defined turnouts (Figures 2 and 11) in the primary canals and the presence of relatively dense scatters of ceramics and artifacts. The latter suggests that household garbage was used as mulch and fertilizer (see Donkin 1979:2; Neely et al. 1990:134-135; Roberts and Barrett 1984; Stewart and Donnelly 1943:42-43; Wilken 1969:231; Wilkinson 1982). In addition, several fields were clearly evident on aerial photographs (e.g., 9-29-78 BLM 24CN AZ-78AC 1-8-69). Four of the best defined fields, representative for this portion of canyon, were approximately 43 by 54 m (2,322 m^2), 64 by 93 m (5,952 m^2), 93 by 122 m (11,346 m^2), and 100 by 143 (14,300 m^2) in size. The estimated maximum total area involved in irrigation agriculture in this west part of the north segment of the canyon is about 38 hectares.

From the offtakes in the primary canal, small secondary canals course toward the east through the areas suspected to be remnants of unimproved prehistoric fields. What appear to be even smaller tertiary "field ditches", or perhaps furrows, branch from these secondary canals. The field ditches or furrows course in what appear to be a sinuous pattern through the fields, crossing the contours of the gentle slope of the ground surface only enough to provide a slight slope to promote the gravity flow of the water through the channel. The field ditches or furrows course from one side of the plot to the other in a back-and-forth meandering fashion until they reach the lowest corner of the field. There they appear to empty onto areas that probably served as floodplain fields further down-slope, and ultimately to flow eastward into the Lefthand Canyon drainage. It should be

noted that the above description of the fields is more of a vague perception than a set of well-defined, observable characteristics. It would be highly desirable to "shave off" from 5 to 10 centimeters of the topsoil of portions of one or more of these fields to verify and augment the description provided above.

Because these cultivated areas were situated between the linear arrangment of habitation sites (Figure 2), there was a question as to whether some of these areas should be classified as "fields" or as "gardens" (Turner and Sanders 1992:265-266). Most were classified as "fields" because of their large area and because smaller plots were discovered in even closer proximity to some of the sites. Site AZ.CC:1:52 (ASM), on the west side of the canyon, provided an excellent example of a garden. This site occupies a small rinco*n* on the first terrace above the floodplain. A small rock-bordered ditch branches from the primary canal that follows the contours just above and west of the site. This ditch courses down onto the rincon's living surface to supply water to a small garden indicated by rocks forming linear bordered and gridded areas (Rinker 1998:Figures 3.11, 3.12). The area of this garden is at least 130 m^2, but, because this area had been disturbed by looting, it probably was originally larger.

As the easterm most canals recorded on the west side of the drainage (Figure 2) lead to the floodplain, irrigated floodplain fields were evidently also present. In a few areas, remnants of rock-bordered fields were seen. Their vagueness is due to the natural erosional and alluviational processes that characterize all floodplains. The apparent alignments on the floodplain in these areas probably represent features analogous to the "channel-bottom weir terraces" reported by Doolittle (1988:48-50). If so, they could represent a combination of irrigation, floodplain, and floodwater field technology.

Generally similar canals and fields were found in the Safford Valley by Clark (2002) on the floodplain of the Gila River, elsewhere in the Southwest (e.g., Neely 1993, 1995b), and in several locations in Mexico (e.g., Doolittle 1988; Neely et al. 2005; Woodbury and Neely 1972).

Dry-Farming/Runoff Agriculture. Recognition of dry-farming or runoff agriculture for the entire canyon is based largely on the presence of habitation site location, specific artifact types, and water-management features; all of which lend insights as to the possible or probable presence of fields. The present sample suggests that a broad range of field sizes (from about 100 m^2 to over 10,000 m^2) were used. In addition, a range of topographic and geographic locations were used, and in specific topographic situations the field size range and the use of certain water-management features appear to be positively correlated. While dry-farmed fields in the Safford Valley mostly date from the Late Formative and Classic periods, the tradition can be traced back into the Early Formative period. The numerous dry-farmed fields in the Lefthand Canyon area mirror those found throughout the Safford Valley, and indicate that they played an integral role in the subsistence and economic systems.

In Lefthand Canyon, as throughout the Safford Valley, the Early Classic period (A.D. 1150 - 1300) communities were often surrounded by extensive dry-farming systems that consisted of rockpiles, stone grids, linear borders, check dams, and terraces (Gilman and Sherman 1975; Neely 2004; Neely and Doolittle 2004; Seymour and Euler 1990; Seymour et al. 1997a). These systems were evidently used in a symbiotic relationship with the expanding irrigated agricultural systems in marginal non-riverine settings such as in Lefthand Canyon. The characteristics of the Early Classic dry-farming fields appear

much the same as those fields dating to the Late Formative period. It seems likely that many of these fields would have gone out of use because of the severe lack of precipitation during the "Great Drought" years between A.D. 1275 and 1299 (Dean and Robinson 1982:Figures 8.3 and 8.6). However, the Late Classic period (A.D. 1300 - 1450) witnessed the final expansion of large upland dry-farming systems (Neely 1997a, b; Neely and Rinker 1997). The upland settlements in the Safford Valley, including those in Lefthand Canyon, were evidently abandoned by about A.D. 1385; as indicated by the absence of key diagnostic ceramic types at any of the sites recorded. Some (e.g., Bradfield 1971:18; Glassow 1980:45) have opinioned that dry-farming was probably a minor contributor to the subsistence base in the Southwest. However, recent studies in the Safford Valley (Doolittle and Neely 2004) and the Tucson area (Fish et al. 1992) have shown dry-farming to play a significant role in supplying food and fiber to the economy. For example, about 10 km to the south-southeast of Lefthand Canyon, the rock-bordered grid system (gridded fields) located north of the present community of Bryce, Arizona (Doolittle and Neely 2004) forms the largest dry-farming system yet recorded in the Safford Valley. The system was constructed within an area of approximately 6.0 km^2, and consists of 15 to 33 (depending on how one interrelates the gridded areas) irregularly juxtaposed, but separate, areas of rock-bordered grids. They comprise a total gridded area of about 822,000 m^2 (82.2 hectares or 203 acres). It is estimated that a maximum of seven percent (about 57,500 m^2 or 5.75 hectares) of those fields were constructed beginning early in the Late Formative period (Neely and Doolittle 2004). The remaining fields were constructed in the subsequent Classic period.

A number of studies (e.g., Fish et al. 1992; Doolittle and Neely 2004; Seymour et al. 1997b), have convincingly shown that many, if not most, of the dry-farmed fields that depended solely or predominantly on direct precipitation for moisture were dedicated to the cultivation of agave for the production of mescal, and very probably other by-products (cf., Parsons and Parsons 1990). It seems highly probable that the dry-farmed fields in the Lefthand Canyon area served a similar purpose. A feature frequently found adjacent to the dry-farmed fields is the roasting pit. The excavation of these features will undoubtedly provide insights into the crops grown in the associated fields as well as dates when the fields were most likely cultivated. Radiocarbon samples recovered from a roating pit in Lefthand Canyon were dated to A.D. 1185-1267 (TX-9258) and A.D. 1374-1452 (TX-9259).

Chronological Placement of the Canal Systems and Sites

The chronological placement of the water management and irrigation features, as well as the associated habitation sites, has been largely based on surface ceramic collections, although a few test excavations have provided stratified remains as well as archaeomagnetic and radiocarbon dates.

The Southern Segment of the Canyon

Based on proximity, the canals and fields in the southern segment of the canyon most probably resulted from the efforts of the inhabitants of the Goat Hill site. This site, the only site recorded in this segment of the canyon, has been dated by excavated archaeomagnetic and radiocarbon assays, as well as pottery, to the period of A.D. 1275 to 1325 (Woodson 1999). This chronological placement is supported by the few ceramic sherds seen on the nearby garden and field surfaces during survey.

The Northern Segment of the Canyon

Unlike its southern counterparts, many sherds were found associated with the canals, gardens, and fields of the northern segment. The water management and irrigation agriculture in Lefthand Canyon may be seen as a system that has been augmented through time. The northern portion of the canyon was first used late in the Early Formative period, perhaps as early as ca. A.D. 700-750. A few sherds of the earliest ceramics, Cerros/Three Circle Red-on-white and Pinaleño Red-on-brown, were found at two multi-component sites on the west side of the drainage (Figure 2). It is not known if the canal associated with these two sites dates this early. However, it is evident that the major occupations were during the subsequent Late Formative and Classic periods, and persisted as late as A.D. 1385 before abandonment. Five of the sites, all on the east side of the drainage (Figure 2), date only to the Late Formative period (ca. A.D. 800 to 1100), and four sites date only to the Classic period (ca. A.D. 1100 to 1450). The remaining nine sites are multi-component, with two sites on the west side of the canyon having the few sherds dating to late in the Early Formative period.

The dating of the large Spear Ranch site (AZ. CC:1:11 [ASM]) is not well established, but test excavations there by Eastern Arizona College recovered ceramics that spanned the period of ca. A.D. 900 to 1400 (Jernigan, personal communication, 1995). Assessment of the surface ceramics, as well as a review of the ceramic types reported by Jernigan and Woodbury (1959), supports the ca. A.D. 900 date for the founding of the site, but the decoration and vessel forms of Gila Polychromes found suggest a terminal date of ca. A.D. 1385. This would indicate that the Spear Ranch Site was occupied

before the Goat Hill site, and had sustained its occupation after the Goat Hill site was abandoned.

Observations

The Foothill Settlement Pattern

Although the focus of this paper is on Lefthand Canyon, a reconnaissance of the northern foothills of the Pinaleño Mountains revealed that foothill systems had been constructed along the entire northern face of the mountains; evidently where ever springs and drainage catchments of sufficient size were present. The Taylor Canyon system (AZ.CC:1:70 [ASM]; Neely and Rinker 1997), about 5 kilometers west of Lefthand Canyon, was the system recorded furthest to the west (Figure 1, Locus 1). The Jacobson Canyon system (Neely and Crary 1998), about 26 kilometers southeast of Lefthand Canyon, was the system recorded furthest east (Figure 1, Locus 7). In scale, the Taylor Canyon canal was the smallest and least complex system found, while the Marijilda Canyon system (Neely and Crary 1998), associated with the Marijilda site (AZ.CC:5:6 [ASM]) and located some 19 kilometers southeast of Lefthand Canyon, was the largest and most complex system recorded (Figure 1, Locus 6). Evidence from the seven systems varies greatly in quantity and quality. This distribution is verified and expanded by the observations of Bandelier (1892), Hough (1907), and Sauer and Brand (1930). In addition, Bandelier's (1892:414) reference to yet another canal with branches lying in a similar topographic situation about “12 miles” southeast of Globe, Arizona also implies that the systems reported herein are not unique to the Safford area.

The foothill canals found begin at elevations as high as 1,311 meters (about 4300 feet) and extend northward to elevations as low as 845 meters (about 2770 feet). The head of

many of the systems is represented by the presence of a spring or the most likely point of offtake from a spring-fed stream, although augmenting runoff from precipitation and snow-melt comes from much higher elevations. The terminus of the systems has been placed at the furthest point downslope that the system can be traced, although it is likely that some of the systems recorded were more extensive than indicated by surface evidence visible today. While the seven systems shown on Figure 1 do not extend northward to the Gila River floodplain, findings at the Bandelier site (AZ.CC:1:7 [ASM]) indicate that this site, situated at the edge of the first terrace above the floodplain, received water from a canal coming from the foothills of the Pinaleño Mountains (Bandelier 1892:410; Neely and Rinker 1997). The documented foothill canal systems range from about 600 meters to 12.5 kilometers in length. The Marijilda Canyon system is the largest recorded; with a watershed collection area of at least 28.3 square kilometers (USGS 1998), and an additional 15.5 square kilometers of watershed probably augmenting that system from the adjacent Deadman and Rincon Canyons (USGS 1998). Considering its juxtaposition and contemporaneity with other agricultural and settlement patterns now known for the Safford Valley (e.g., Clark 2002; Neely 2004; Neely and Doolittle 2004), it is unlikely that the foothill pattern existed as an isolate, completely separate from other contemporary manifestations. The combined use of the foothill and other agricultural and settlement manifestations may at least partially be explained as a superbly adaptive solution to a lack of available moisture (Neely 2004). This pattern is seen as a part of the intricately interconnected use of multiple microenvironmental zones for the production of a varied agricultural crop and to protect the agriculturalists from the vagaries of unpredictable precipitation (Neely 2004; Neely and Doolittle 2004).

A major advantage of the foothill systems was a frequent availability of water for the entire year. Interviews with local inhabitants as well as BLM and Forest Service personnel indicate that snowmelt is present and springs function on the north side of the Pinaleño Mountains frequently nine to 10 months of the year into the first week or two of July, when the monsoonal rains start. This insured year-round water availability for domestic use and probably enough water for irrigation farming to permit several well-planned crops during the over 200 day growing season this area usually enjoys (Bronitsky and Merritt 1986:21, 24; Sellers and Hill 1974:422). It probably was this water availability characteristic that made Lefthand Canyon, and the other foothill systems, habitable and very desirable, during the "Great Drought" years between AD 1275 and 1299 (Dean and Robinson 1982:Figures 8.3 and 8.6). The foothills would have been a not already heavily occupied location for habitation for the migrants from the four-corners region who arrived in the Safford Valley at this time.

A Highland-Lowland Pattern. The use of the foothills vis-à-vis the Gila River floodplain may represent a form of highland-lowland or infield-outfield (Wolf 1966:21) land use. Similar highland-lowland patterns are documented for both ancient and modern cultures throughout the world (e.g., Fish et al. 1992; Kirkby 1973; Özfirat and Helwing 2004; Vogt 1969). There also appears to be a highland-lowland pattern present during the Classic period along the Gila River in the Casa Grande region (Crown 1987), and during the Reserve phase (ca. A.D. 900 to 1100) in the San Francisco River drainage between the lowland WS Ranch Site (LA 3099) near Alma, New Mexico and the highland sites of Devils Park to the east in the Gila National Forest (Accola 1981; Neely, personal observation, 1980; Peterson 1988). Pool (1985) has suggested that the prehistoric

Mogollon practiced a semi-sedentary annual round of subsistence procurement generally similar to that documented for the Apache. While the latter pattern suggested for the Mogollon is not as similar to the pattern seen in the Safford Valley as those from south-central Arizona (Fish et al. 1992) and west-central New Mexico (Neely, personal observation, 1980; Nelson and Anyon 1996), it does suggest a similarity in the subsistence/economic pattern that utilized several environmental zones. Interestingly, interviews with Safford Valley agriculturalists and ranchers document a similar historic and present day highland-lowland pattern of families using lands on the floodplain for farming as well as in the foothills for cattle grazing.

However, because of the presence of springs and large runoff areas, the Pinaleño Mountain foothills comprise a special form of highland-lowland relationship with the Gila River floodplain. This is a relationship evidently not present in the nearby San Pedro Valley (Patricia Cook, Jeffery Clark, Henry Wallace, e-mail correspondence, 2004) or Tonto Basin (Van West and Altschul 1994:362). At this stage of study, the uniqueness of the Safford Valley foothills seems to be due to physiographic and hydrological differences rather than cultural differences.

Origins of the Foothill Agricultural System

The origins of the foothill agricultural systems in the Lefthand Canyon are not clearly discerable. However, the survey and test excavations provide some insights.

The Southern Segment of the Canyon. The rock-bordered canals characterizing the southern segment of Lefthand Canyon are relatively unusual features and do not have many analogs. Those that are known suggest influences from the north. Similar rock-bordered irrigation systems have been found in the Verde Valley (Fish and Fish 1984)

dating to ca. A.D. 1200-1350, in the Upper Little Colorado region near Springerville, Arizona (Fred Plog, personal communication, 1978) dating to ca. A.D. 1000-1300, and in the Glen Canyon area of southeastern Utah (Lindsay 1961) dating to ca. A.D. 1050-1250. Considering the forgoing in relation to Woodson's (1999) findings at the nearby Goat Hill site, it seems probable that the agricultrural fields and canals in the southern segment of Lefthand Canyon represent a construction effort by migrant Anasazi peoples. This probability is reinforced by the recovery of only Maverick Mountain Black-on-red and Polychome sherds among the canals and fields.

The Northern Segment of the Canyon. The canals and fields in the northern segment of Lefhand Canyon have a longer and different history from those to the south. There, the surface ceramics and associated habitation and activity sites suggest a local development, probably with Hohokam influences, beginning several centuries before the construction of the Goat Hill site. It is not known if the residents of the northern segment influenced the agricultural constructions of the southern segment occupants when they occupied the canyon, or if certain aspects of the southern agricultural constructions (e.g., the rock-bordering of canals) were subsequently adopted by the northern occupants through influences from the southern group.

The Question of CCC Origins. One of my colleagues, who has worked in the Safford Valley for many years and knows the archaeology of that area extremely well, has doubts regarding the prehistoric origin of some of the Lefthand Canyon terraces, and more specifically the stone-lined or stone-outlined "splashpads." He contends is that the splashpads and their associated terrace walls are, in fact, erosion prevention features constructed by the Civilian Conservation Corps (CCC) early in the 20th century. He

supports this contention with the discovery of similar features constructed in proximity to the Sanchez CCC Camp, located above the north bank of the Gila River some 6.0 kilometers to the northeast of Safford, Arizona. I too have found similar features associated with CCC constructions at site AZ. CC:1:69, the Taylor Canyon CCC Site.

In respect of my colleague's opinion, I investigated this possibility thoroughly during my fieldwork. I have found a number of lines of circumstantial evidence that point to their prehistoric origins. Allow me to briefly enumerate these lines of evidence.

1) These features are found on privately owned (patented) land, including the Spear Ranch. Interviews with elderly members of the Lamb and Smith families, past and present owners of the Spear Ranch since circa. 1880, revealed that they have no knowledge of the CCC having done any work on their property. Discussions with several local historians and life-long residents of the area (Mr. Lee Krider [Pima, Arizona - 86 years of age], Mrs. Mary Long [Pima, Arizona - about 75 years of age], and Mr. Frank Quinn [Safford, Arizona – 90+ years of age], indicate that their perception of the CCC mandate did not include its presence and modification of the landscape on private lands. Further investigation of this perceived CCC mandate is being made in correspondence with the CCC Museum at Jefferson Barracks, near St. Louis, Missouri.

2) The spash pads occur, sometimes in a rather scattered or inconsistent distribution, amidst the prehistoric fields and canal systems. The question then arises as to why would the CCC come into an area and modify portions of the existing prehistoric systems? In addition, S. Christopher Caran, a professional geologist specializing in Holocene geomorphology and hydrology, examined the field area just below and west of Goat Hill. His findings were that the ground surface of the canal and field area was stable, and that

minimal erosion had taken place since the canal and terraced fields were abandoned. Among the indicators of this stability is the extremely fine preservation of the surface details of the canal and the fields. Again a question, why would the CCC construct erosion prevention features on a stable land surface?

3) A possible explanation to this quandry was found in January of 2004, when Doolittle and Neely last visited the Safford Valley. Just north of the Safford Airport and west of the Sanchez CCC Camp we found what we interpret to be CCC constructions overlapping prehistoric features at slightly different angles. Our interpretation of these overlappings is that the CCC was duplicating and enlarging the original prehistoric features and systems of water and soil management. Thus, the similarities of check dams, linear borders, and splash pads found at prehistoric sites and at CCC sites are by no means fortuitous. The recognition of the prehistoric features and systems as efficient erosion preventing technology by the CCC apparently resulted in their replication by the members of that government agency. Such an eventuality seems entirely possible in the light of the reuse of the prehistoric canals by the historic agriculturalists of the Safford Valley (Neely 2004:30).

Socio-Political Complexity in Lefthand Canyon

Following the doctrine proposed by Stark (1993), regarding the collection of empirical data as they apply to the development of models and theoretical frameworks, it is necessary to provide tangible evidence for the generation of models. The subsistence system, with its focus on agriculture and its associated technology, is an important variable in reconstructing the processes of cultural change documented by the archaeology of the Safford Valley. However, in spite of the importance of climatic

conditions and the subsistence system, the socio-political system of the prehistoric inhabitants must be considered as primary in directing the processes of change documented.

Recognizing the problems of neoevolutionary terminology (Yoffee 1993), the level of socio-political organization implied by the subsistence and settlement patterns, the nature and size of the sites and associated canals and fields, suggests an organization that would conform to that which Sahlins (1961, 1968, 1972), Schneider (1965), Service (1962), and others have labeled as "tribal."

This would entail relatively small egalitarian groups such as lineages or clans (e.g., Levy 1992:8; Schlegel 1992:381) having tenure to agricultural fields and infrastructure in two or more microenvironmental zones (e.g., the Pinaleño Mountain foothills and the Gila River floodplain).

A model based on the ethnohistoric O'odham has been presented for the prehistoric social organization of the Safford Valley area (Neely 1997b), and appears to be applicable in this case as well. In summary, this model proposes that even the most complex and extensive communities and public works of the Safford Valley were constructed and used by peoples organized at a "tribal" level. The model postulates social, political, and religious organization changes, as well as modification in agricultural technology, to accommodate and adapt to stresses occurring between ca. A.D. 750-1400 that resulted from climatic degradation, population increases, and possible intercommunity conflict. The model proposes the early presence of an essentially egalitarian society organized by kinship and employing "Chanayov's rule" (Sahlins 1972:87), an optimizing strategy to "store" labor potential in reserve to be used in

emergencies to insure the survival of the household. As stresses build though time, more complex kinship-based organizational integrating mechanisms and religious organizations are adopted. These mechanisms for organization and integration operated as a horizontal form of stratification similar to the "sequential" or "modular" hierarchy described by Johnson (1982, 1989). The development of a horizontal form of socio-political organization would not require major reformulations of the system existing since the Early Formative period. It is proposed that the O'odham-based model briefly summarized above potentially could account for the construction of all of the habitation sites, including the large Spear Ranch site, as well as all of the associated canals, gardens, and fields.

Conclusion

The excellent preservation in Lefthand Canyon has provided insights into the foothill water management and irrigation system as another form of agricultural maximization employed by the ancient inhabitants of the Safford Valley. Its extensive use in environmentally propitious locations along the northern face of the Pinaleño Mountains indicates that the foothill system played an important role as part of the adaptive process in confronting the problems presented by variations in available moisture and probable socio-political pressures resulting from an increasing population of local and ethnically diverse immigrant peoples (Neely 1997b, 2004; Neely and Doolittle 2004).

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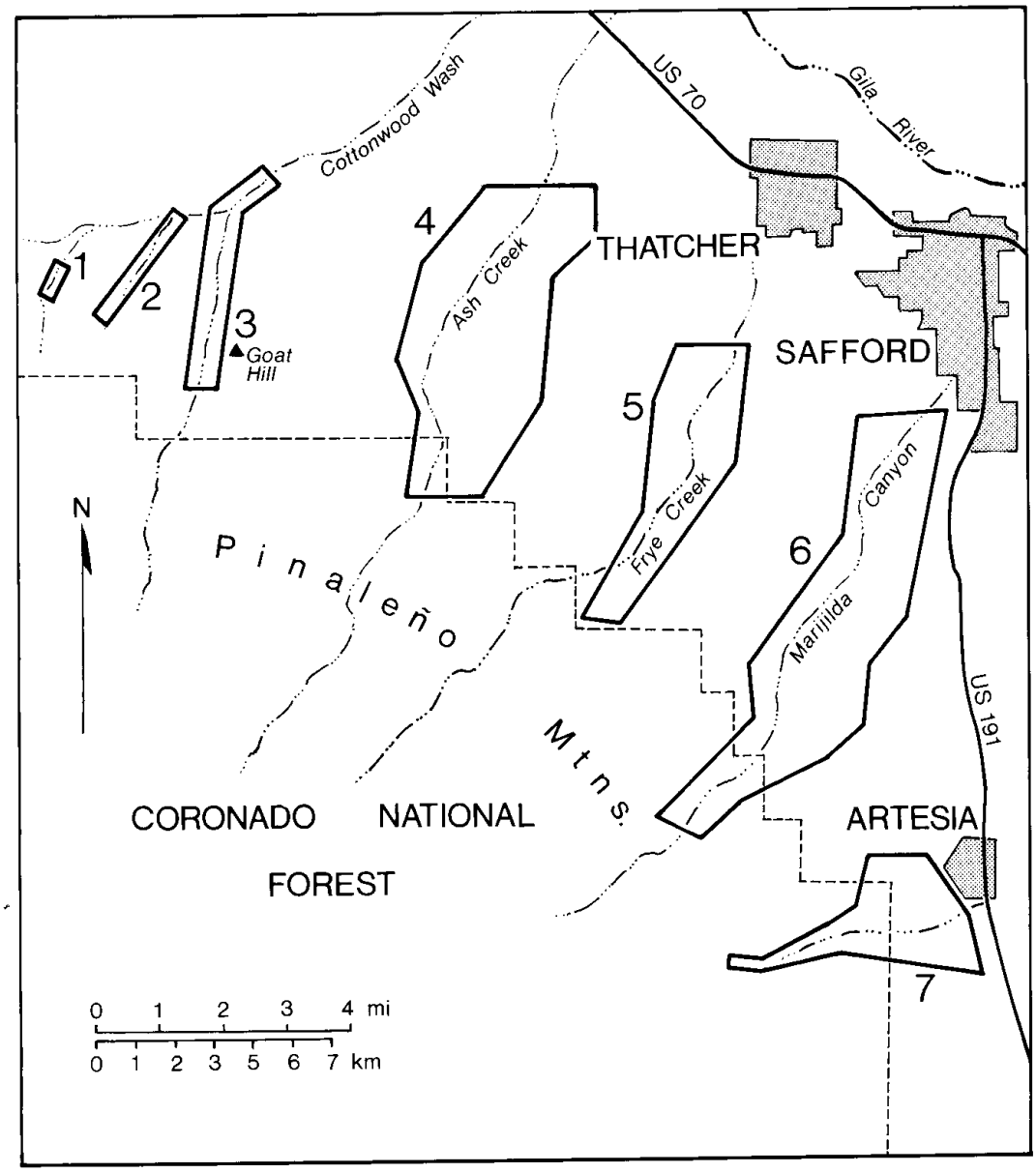

Figure 1. A schematic map of the seven habitation and agricultural areas recorded in the foothills on the northern face of the Pinaleño Mountains. The seven areas are: 1, Taylor Canyon; 2, Sand Wash - Middle Wash; 3, Lefthand Canyon; 4, Ash Creek Canyon; 5, Frye Creek Canyon; 6, Marijilda Canyon; and 7, Jacob Canyon.

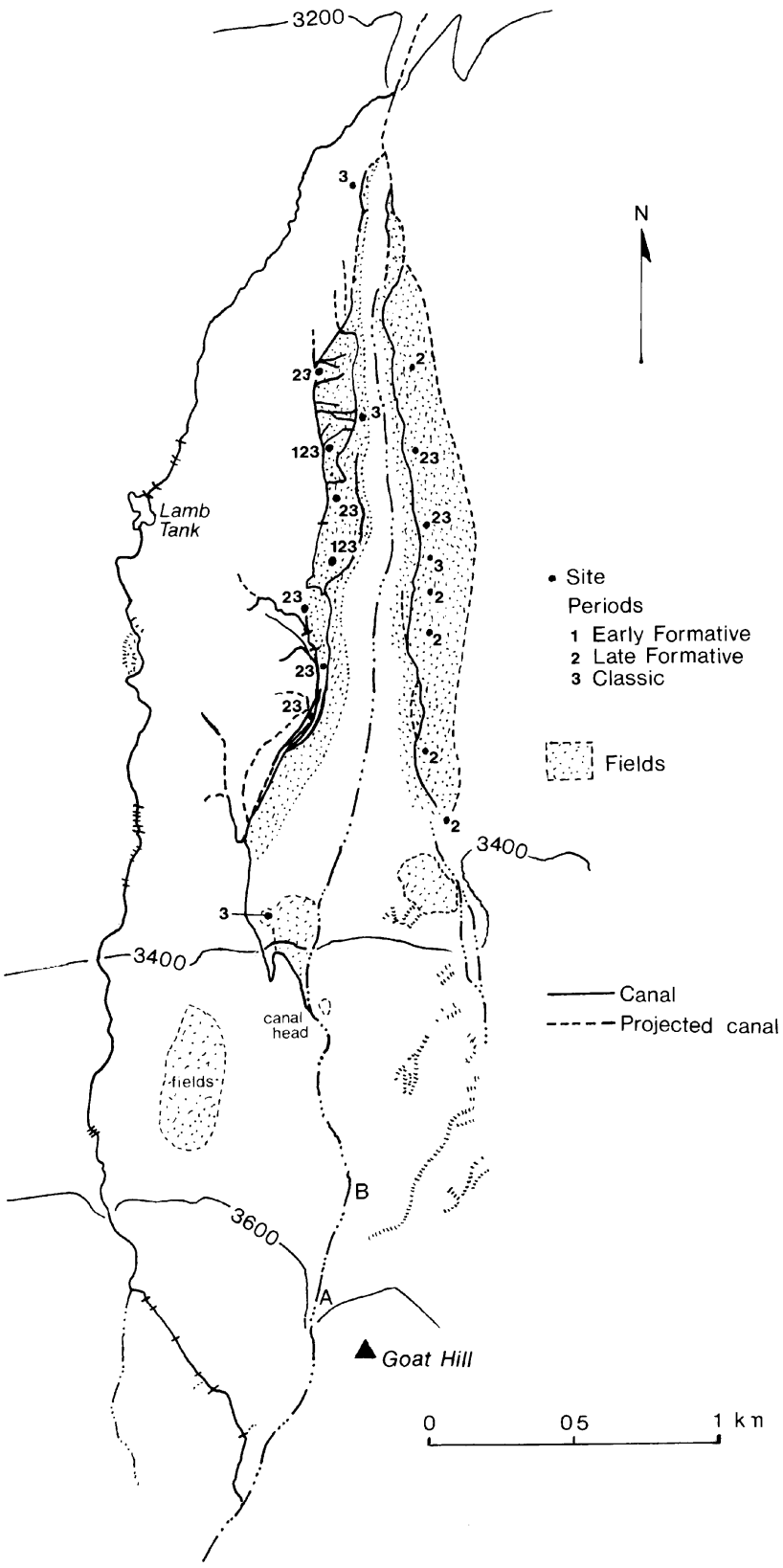
3200
3400
3400
3600
Lamb Tank
canal head
fields
A
B
Goat Hill
N
• Site
Periods
1 Early Formative
2 Late Formative
3 Classic
Fields
Canal
Projected canal
0
0.5
1 km

Figure 2. A map of Lefthand Canyon, showing locations of the habitation sites, canals, and agricultural fields. Note that "A" and "B" match the same letters found on Figure 3, and serve to locate the agricultural canals and fields from the south segment of the canyon on this map.

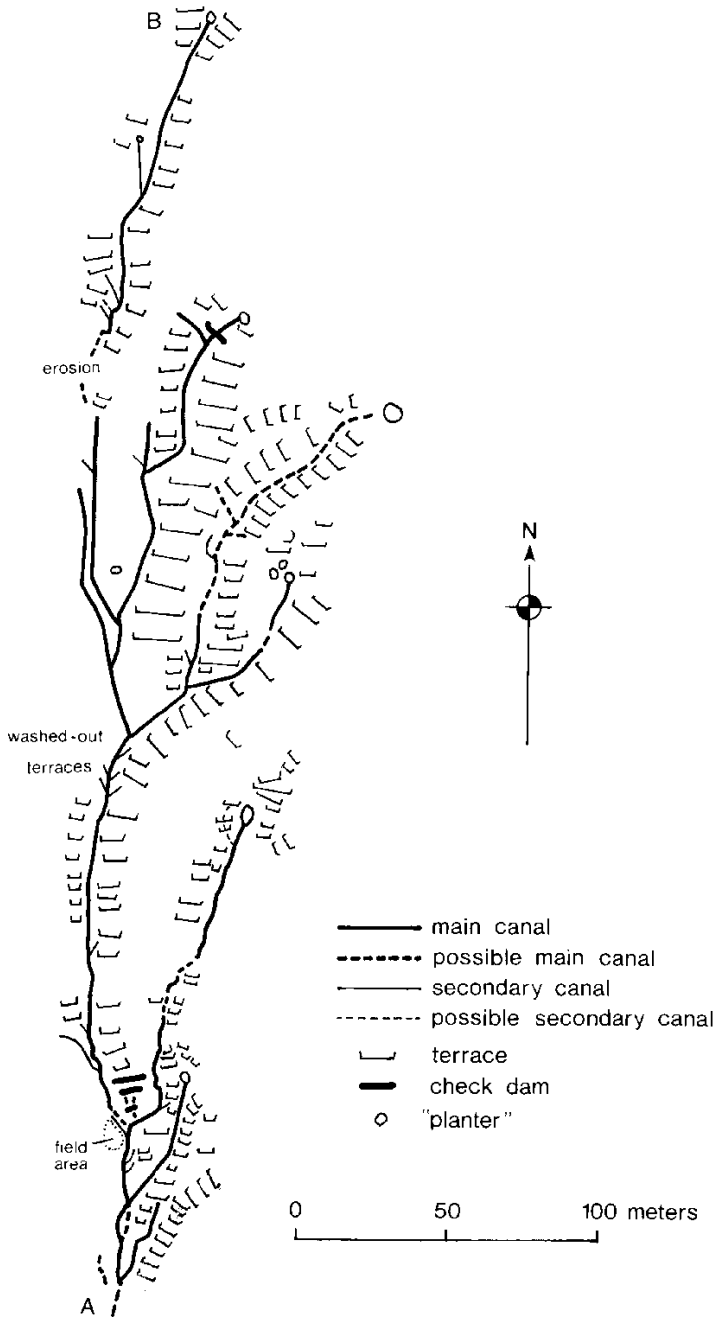
B
erosion
washed-out
terraces
field
area
A
N
main canal
possible main canal
secondary canal
possible secondary canal
terrace
check dam
"planter"
0
50
100 meters

Figure 3. A map of the rock-bordered canals and rock-faced terraced fields located just west and below the Goat Hill site in the south segment of Lefthand Canyon.

Figure 4. A well-defined portion of the rock-bordered canal located just west and below the Goat Hill site in the south segment of Lefthand Canyon.

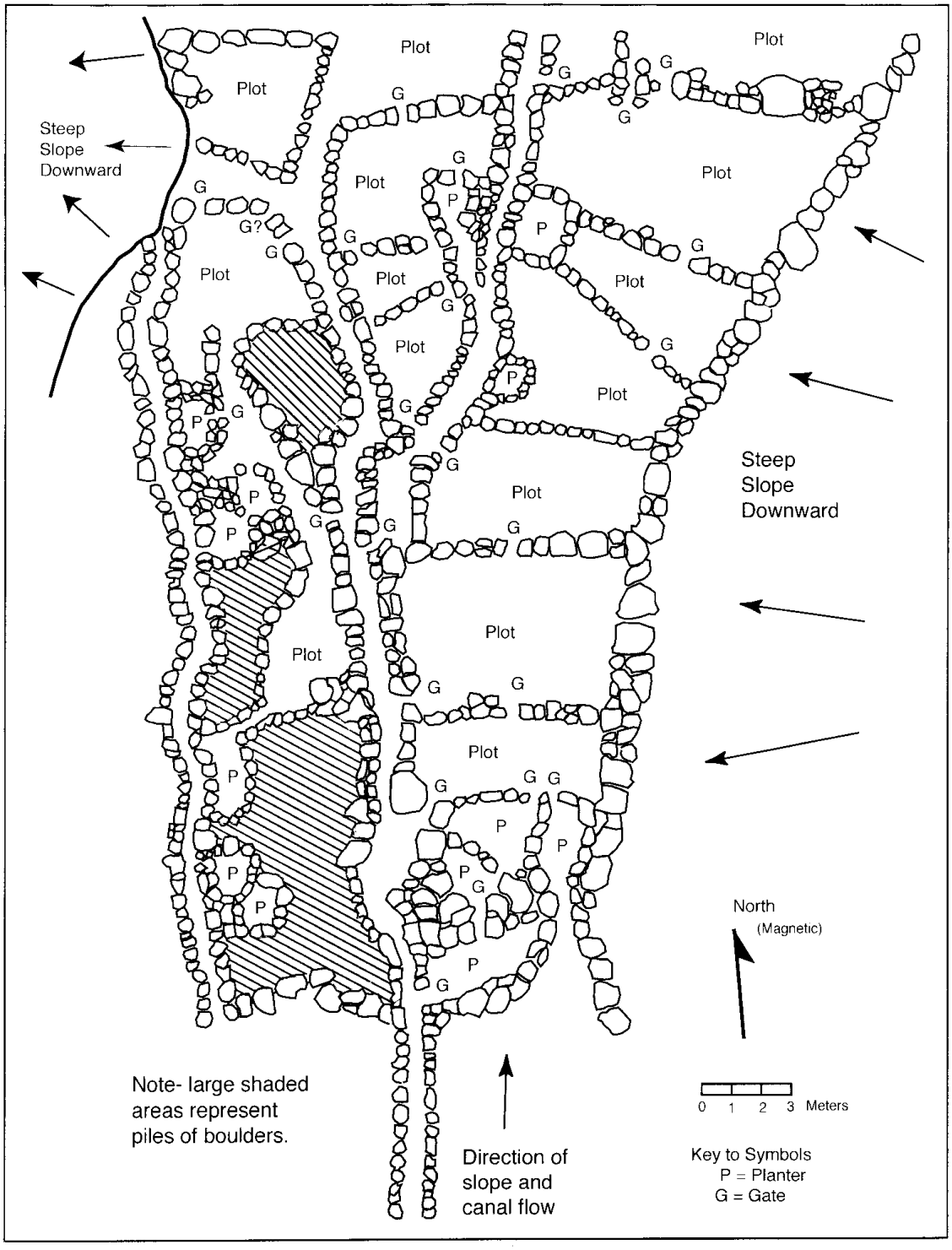

Figure 5. A detail map of the garden area lying just west and below the Goat Hill site in the south segment of Lefthand Canyon.

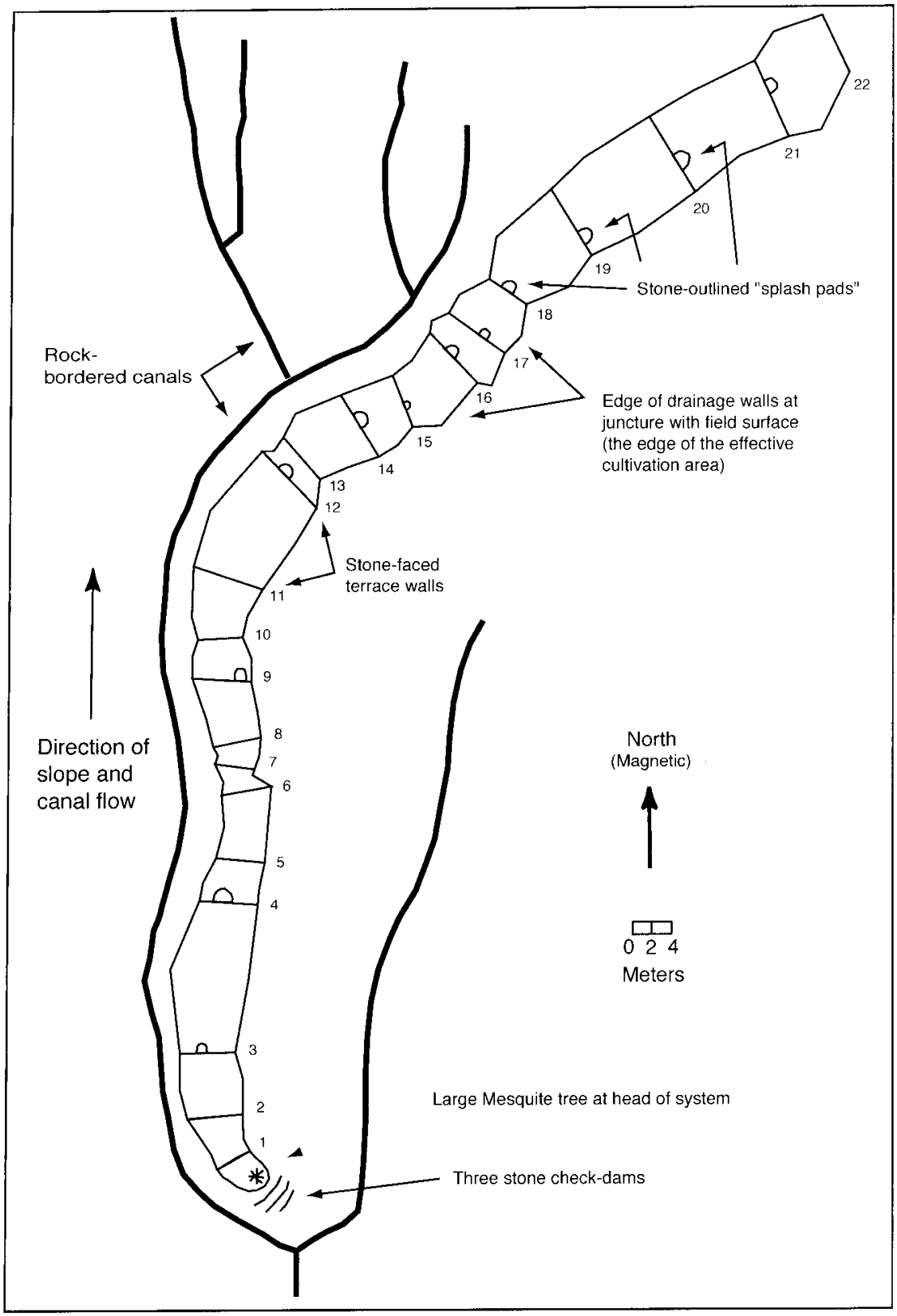
22
21
20
19
Stone-outlined "splash pads"
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
Rock-
bordered canals
Edge of drainage walls at
juncture with field surface
(the edge of the effective
cultivation area)
Stone-faced
terrace walls
Direction of
slope and
canal flow
North
(Magnetic)
0 2 4
Meters
Large Mesquite tree at head of system
Three stone check-dams

Figure 6. A schematic map of 22 of the rock-faced terraced fields located in one of the "erosion" channels in the southern portion of Lefthand Canyon. See Figures 7 and 8 for photographs of portions of this terraced field system, and Figures 9 and 10 for photographs of "splash pads."

Figure 7. Looking up-slope in the "erosion" channel shown in Figure 6. Note the figure standing in the mid-background for scale.

Figure 8. A side view of rock-faced terrace #14 in the "erosion" channel shown in Figure 6, showing the placement of the rock-faced terrace and the splash pad shown in Figures 9 and 10. Note the figure standing in the mid-background for scale.

Figure 9. Looking down-slope onto a well defined “splash pad” found at the down-slope face of rock-faced terrace #14, shown in Figure 6.

Figure 10. Looking up-slope onto the well-defined splash pad found at the face of rock-faced terrace #16, shown in Figure 6.

Figure 11. A small secondary canal sluice or gate exposed by excavation. Note the "armored" pylons to either side of the offtake, as well as the shallow channel of the secondary canal and its surface indications extending down-slope toward the top of the photograph.