Three-Dimensional Visualization of Landform-Sediment Assemblages and Military Disturbance Processes at Fort Riley, Kansas

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Technical Report

William C. Johnson, Ph.D.

Department of Geography
University of Kansas

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Introduction

Several years ago, archaeologists recognized that the preserved record of past cultural activities is evidence of, with varying degrees of accuracy, both the articulation of human groups and their environment and the effects of post-occupational processes on the material remains of those activities (e.g., Schiffer, 1976; Binford, 1981; Wood and Johnson, 1978). The database is not inherited in a pristine condition, however, in that the archaeological record is an imperfect mirror of past cultural activities that formed vulnerable, "fossil" configurations, which are in turn usually flawed by a variety of post-depositional processes, both cultural and natural.

We have to realize that the cultural record is limited by erosional destruction of part of the record. As Ager (1973, p. 34) notes, "The sedimentary pile at any one place on the Earth's surface is nothing more than a tiny and fragmentary record of vast periods of Earth history." Bettis and Benn (1984), Gladfelter (1985), Johnson and Logan (1990), and a host of others have made the same observation, but in an archaeological context. At Fort Riley, one has to contend with a record of destructive cut and fill episodes within the valleys and with another of water and wind erosion and downslope displacement of upland loess.

Sampling methods for regional and local archaeological surveys have been articulated by many researchers (e.g., Redman, 1974; Plog, 1976; Warren and O'Brien, 1981). As a function of these traditional approaches, resulting studies generally failed to address directly the pervasive problem of erosion (removal/destruction) and deposition (burial), and how they may skew the visible archaeological record. In recent years, archaeologists and earth scientists have routinely joined ranks to address the issue of geomorphic factors that affect site distributions at all scales.

Geoarchaeological research on Fort Riley represents a high-resolution examination of the alluvial and upland eolian record, with the goal of identifying and mapping the remnants of the sedimentary record that contain the potential for cultural remains. Through the use of radiocarbon dating, alluvial surfaces and fills have been dated and extent of Holocene loess on the uplands approximated.

Research at Fort Riley

Geoarchaeological research began with an overview study by D.L. Johnson (1992). On-site work by D.L. Johnson, an assistant and the contractor in June, 1993 involved further reconnaissance, subsurface exploration with a vehicular-mounted coring rig, and documentation and sampling of natural exposures. Eighteen localities, numbered 21-38 and from various landscape positions, were studied through sediment and soil cores. These sites represented various landscape positions within Fort Riley. Of the sites that were cored, all except 21, 26, and 33 extended to bedrock or to the residual soil developed on the bedrock; laboratory analyses were conducted on samples from the cores (D.L. Johnson, 1994). Additional study described the distribution of the loess mantle on the upland and refined the stratigraphy at the Sumner Hill locality, i.e., core site 21 (D.L. Johnson, 1996).

The first evolvement by this investigator centered on paleoenvironmental research. Specifically, tests of the potential for stable isotope ratio analysis (SIRA) of carbon and opal phytolith analysis were conducted to provide proxy time series of climate for the base (W.C. Johnson et al., 1994). Study was carried out on a core extracted from the Sumner Hill locality. Isotopic analysis ($\partial^{13}C$) provided a time series that compares well with a composite of regional carbon isotope data, whereas the opal phytolith record was largely uninterpretable below about 3.5-m depth, i.e., for the lower 8.5 m of the core. On the basis of a recently derived chronostratigraphy of the site (D.L. Johnson, 1996; W.C. Johnson, 1998), the viable portion of the phytolith record does, however, include the time interval related to cultural occupation, i.e., the last 13,000 years or so.

A second part of the environmental reconstruction was designed to consider the record from several sites distributed over the reservation in upland and valley environments. The research design was constructed as to make coincident use of magnetic analysis, SIRA, and analysis of opal phytoliths. Data from this multiparametric approach were of extremely high quality and produced an extractable environmental record.

The next effort continued investigations on the upland loess sequences, but placed emphasis on the alluvial fills of the Republican and Kansas River valleys and selected tributary valleys. Magnetic, isotopic and phytolith studies were continued on the uplands, in conjunction with close-interval radiocarbon dating of selected loess sites. Studies of the alluvial fill focused on the definition and correlation of stratigraphy, combined with radiocarbon dating.

A last focus addressed representation of the stratigraphic and, to a lesser extent, paleo-environmental data in a geographic information system (GIS) context. Distributions of alluvial surfaces and fills and upland loess deposits were rendered, and, from these, probabilities of burial for cultural materials from different periods were generated. This investigation was done in two phases (W.C. Johnson, 1998a, b). Figure 1 depicts the installation and the stream systems and adjacent uplands studied.

Tasks of the 1999 Phase

This contract consists of four tasks, all of which represent a continuation of research conducted in one or more earlier phases of the Fort Riley Geoarchaeological Project. Tasks were to (1) continue to refine the 2-D landscape evolution model; (2) develop a computerized ACCESS database of any existing hard copy records of the "Digging permit" data and render locations and volumetric measurements in a GIS environment; (3) preparation of three-dimensional visualizations of landform sediment accumulations and military disturbances in a GIS environment; and (4) prepare a comprehensive report on the work accomplished and procedures employed.

Fort Riley Military Base
Study Stream Systems

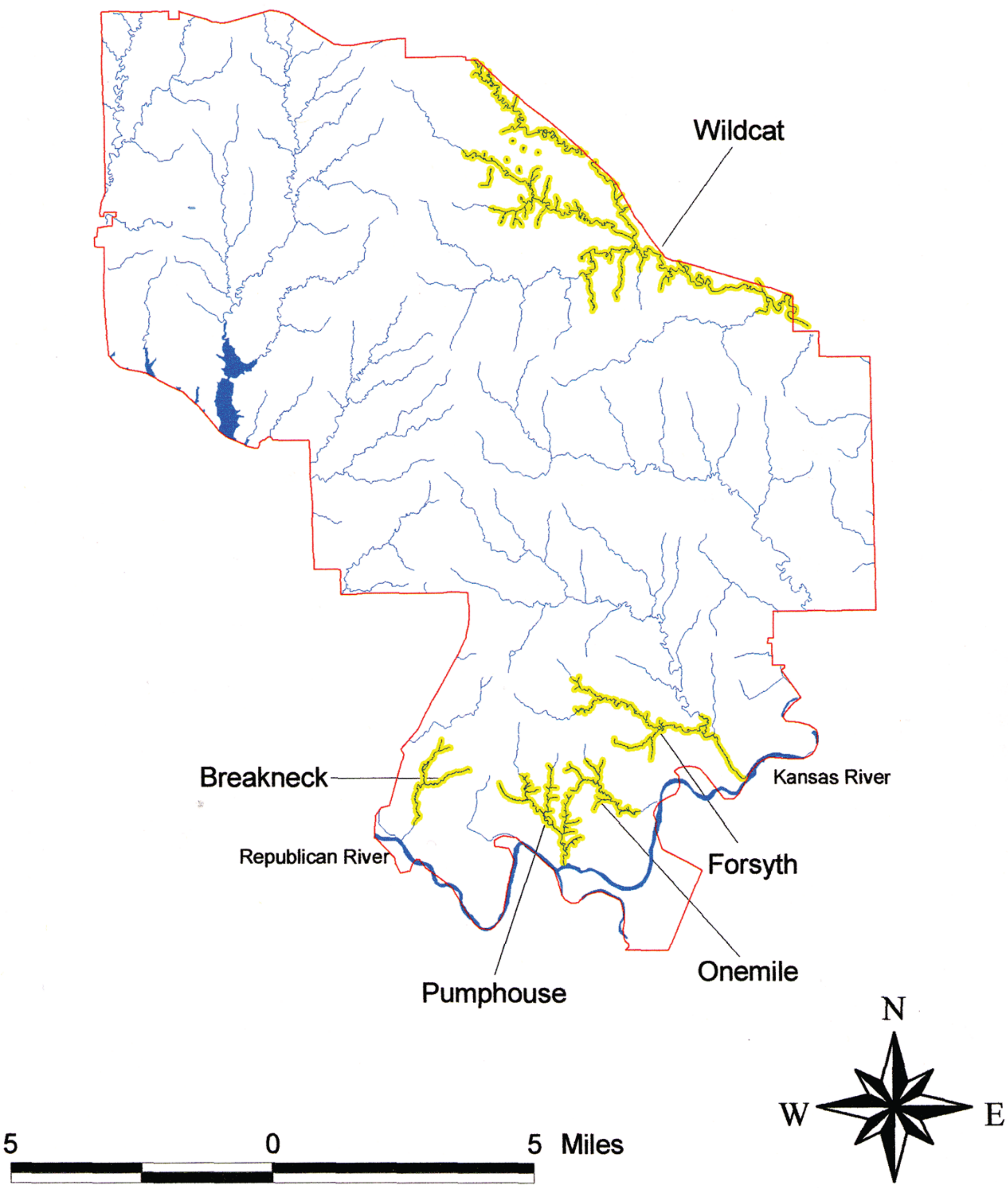


Figure 1

Background to the Research

The distribution, character, and origin of late Pleistocene and Holocene deposits on Fort Riley are, as elsewhere, of direct relevance to realizing and understanding the nature of the prehistoric cultural record. Upland loess and valley fills are the primary late-Quaternary deposits found on the military installation, and these contrasting depositional settings were resource-rich landscapes for prehistoric cultural activities. Because bottomlands offer a particularly rich cultural resource base, the alluvial fills contain a far higher concentration of cultural remains than the upland loess mantle. Considerable research has been conducted on these deposits throughout the region in recent years, with an emphasis on development of chronostratigraphies, but research results from Fort Riley are making a major contribution to the database and to the understanding of paleoenvironmental conditions for the central Great Plains through the high-resolution approach that has been adopted.

A review of the geomorphology and late-Quaternary stratigraphy and climates are presented, as they relate to the taphonomy of the cultural record. An articulation of the regional loess stratigraphy is necessary for the appreciation of the late-Quaternary record preserved at Fort Riley. The stratigraphic and climatic discussion below is abstracted from previous reports.

Regional Late-Quaternary Loess Stratigraphy

A very good empirical relationship exists between cold stages in the marine oxygen isotope record and documented times of glaciation (ice volume) in the United States (Richmond and Fullerton, 1986b). Given the close correspondence between the glacial record and marine isotope record and the fragmentary nature of the former, it follows that the nearly continuous loessal record should be an excellent terrestrial cognate of the marine isotope record. Therefore, the climatic and chronological record assembled for the marine sequence should match the loessal record well. The generally accepted model relating climate to the loessal record indicates that periods of stability and pedogenesis are usually associated with warm interglacials, and periods of significant loess accumulation coincide with the colder glacial times (Kukla 1977, 1987). Figure 2 provides a summary of the regional stratigraphy.

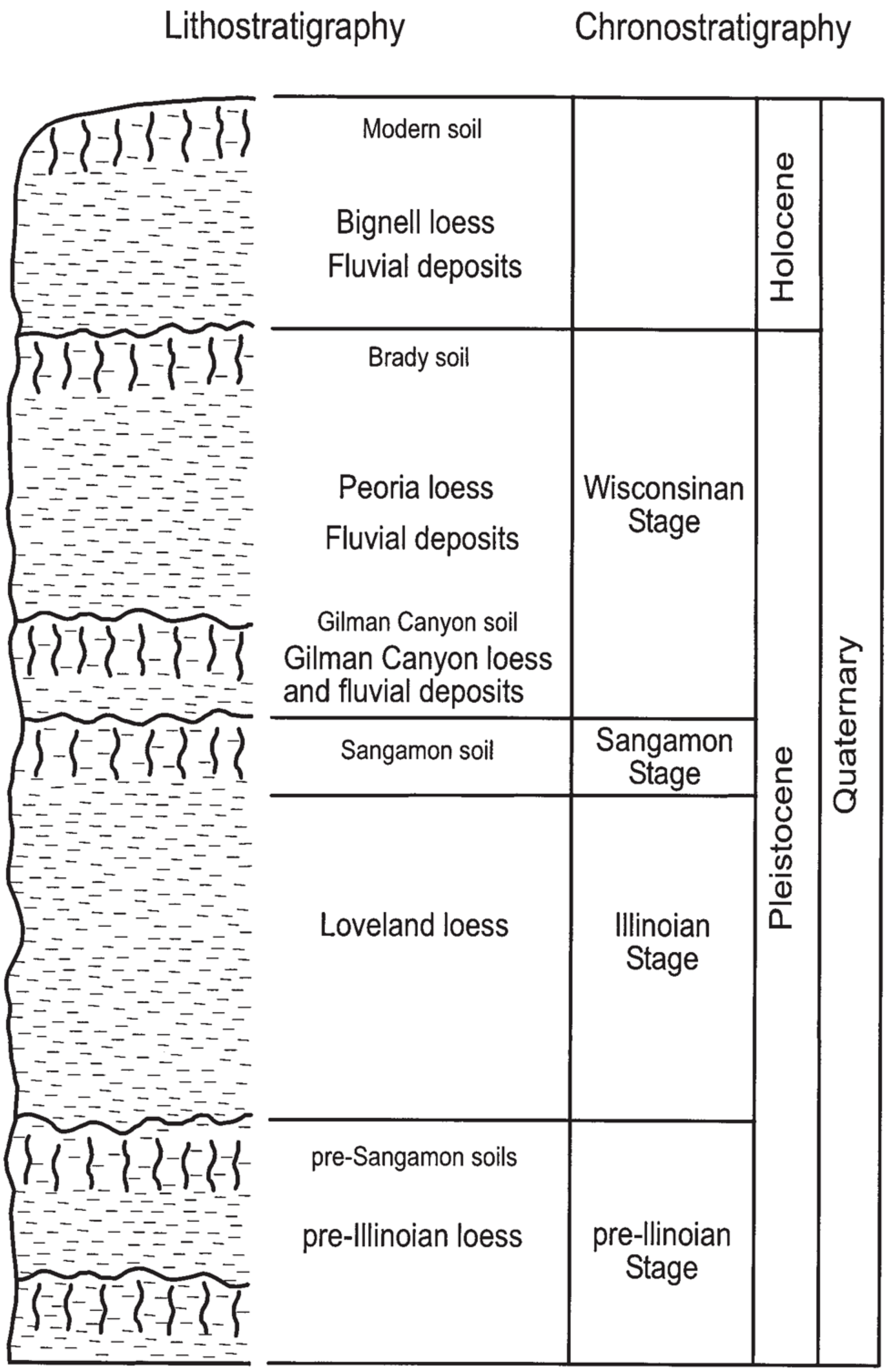

Lithostratigraphy
Chronostratigraphy
Modern soil
Bignell loess
Fluvial deposits
Brady soil
Peoria loess
Fluvial deposits
Gilman Canyon soil
Gilman Canyon loess
and fluvial deposits
Sangamon soil
Loveland loess
pre-Sangamon soils
pre-Illinoian loess
Wisconsinan
Stage
Sangamon
Stage
Illinoian
Stage
pre-llinoian
Stage
Holocene
Pleistocene
Quaternary

Figure 2

Pre-Illinoian Stages

Little is known of the pre-Illinoian loesses because far fewer exposures exist than of the Loveland (Illinoian) loess and certainly the Peoria (late-Wisconsinan) loess. Pedogenesis has been recognized in these early loesses, however. Zones of carbonate enrichment, occurring at about 410-360, 330-290, and 250-200 ka, within the Barton County sanitary landfill exposure were interpreted to be pedogenic in origin (Feng et al., 1994). These carbonate zones are likely analogous to the soils observed in the pre-Loveland loesses at the Eustis ash pit, Nebraska (Fredlund et al., 1985) and elsewhere in the region (Schultz and Martin, 1970; Frye and Leonard, 1951). The zones are temporally equivalent to the nonglacial, or warm marine isotope stages (Feng et al., 1994).

No pre-Illinoian Quaternary sediments have yet been recognized on Fort Riley as a result of this series of CERL-funded studies or are reported in the literature. It appears that major entrenchment and denudation preceded the Illinoian because exposures and cores to date have exposed only what is presumed to be Illinoian-age material overlying bedrock. For example, the Illinoian Sangamon soil, loess, and alluvium rest upon a strath, or bedrock-defended terrace at the Sumner Hill locality; conversely, middle Pleistocene loess rests on an erosion surface developed on limestone at the Bala site and sites 27 and 28.

Illinoian Stage

Stratigraphy associated with this stage within the region consists of the Loveland loess and Sangamon soil. The latter is developed within the upper part of the former; as a consequence, they are often outcropping together.

Loveland loess. The Loveland loess is the most widespread pre-Wisconsinan loess in the Midcontinent. Several investigators (e.g., Reed and Dreeszen, 1965; Ruhe, 1969; Willman and Frye, 1970; Ruhe and Olson, 1980) have described it throughout the Missouri, Mississippi and Ohio River basins. Further, it has been recognized south into Mississippi and Arkansas (McCraw and Autin, 1989). The Loveland has been far less studied (e.g., absolute chronology, geometry, mineralogical composition) than the Wisconsinan loesses, namely the Peoria. The Loveland may be described as a yellowish-brown or reddish-brown eolian silt. Red hues increase toward the top of the formation due to development of the Sangamon soil within the uppermost Loveland. The thickest accumulations occur in the north-central part of the state: recorded thicknesses approach 15 m. A thinning in the loess occurs both southward and westward such that the distribution becomes discontinuous to the southwest. In Kansas, the Loveland is typically less than 10 m thick, but produces a very distinctive mark on the landscape via its variation in stratigraphy. It occurs on uplands and valley side slopes. As a result, the Loveland and its capping Sangamon soil are well expressed in exposures, particularly freshly cultivated fields.

The absolute age of Loveland loess in Kansas is largely uncertain, but recent work at sections exposed in a Geary County quarry in northeastern Kansas, the Barton and Pratt County sanitary landfills of central Kansas, and the Eustis ash pit of southwestern Nebraska provided the first absolute-age information on the Loveland beyond that carried out at the paratype section. Oviatt and others (1988) reported TL ages of 136 ka and 130 ka for the upper part of the presumed Loveland loess exposed in an abandoned quarry near the town of Milford, immediately west of Fort Riley. TL age data from this and others sites in Kansas indicates that the Loveland loess began accumulating sometime before 130 ka (Feng et al., 1994; Johnson and Muhs, 1996). Maat and Johnson (1996) derived a TL age of approximately 160 ka immediately below the Sangamon soil in Loveland loess at the Eustis ash pit.

Sangamon soil. This paleosol is strongly developed and occurs throughout the Midcontinent beneath deposits of the Wisconsinan glaciation and within deposits of the Illinoian glaciation or older deposits. The Sangamon soil has been recognized in Indiana (Hall, 1973; Ruhe et al., 1974; Ruhe and Olson, 1980), Illinois (Bushue et al., 1974; Follmer, 1979) where the type section is located (Follmer, 1978), Iowa (Simonson, 1941; Ruhe, 1956, 1969), Nebraska (Schultz and Stout, 1945; Thorpe et al., 1951) and Kansas (Frye and Leonard, 1952). In Kansas, the Sangamon soil is well expressed, occurring throughout the state. Although the soil has received considerable attention in northeastern Kansas (Frye and Leonard, 1949, 1952; Tien, 1968; Caspall, 1970; Bayne et al., 1971; Schaetzl, 1986), it has been recognized at many localities in the state (Bayne and O'Connor, 1968) and recently studied in central Kansas (Feng et al., 1994). Historically, it has been referred to as a "soil in the Sanborn formation" (Hibbard et al., 1944), the Loveland soil (Frye and Pent, 1947), and the Sangamon soil (Frye and Leonard, 1951). The color of the soil ranges from a vivid to pale reddish-brown, with a loss in color occurring westward. Regionally, the soil character varies according to parent material, local drainage and climate which prevailed at the time of pedogenesis. The soil occasionally contains sufficient clay to create a subtle bench on cultivated slopes. Schaetzl (1986) noted that the soil appears to have been a very strongly developed Ultisol or Mollisol.

The Sangamon soil was first used in a time-stratigraphic context to differentiate deposits of the Illinoian and Wisconsinan glacial stages (Leverett, 1899). An appreciable time span for regional landscape stability and soil formation are suggested by oxidation, apparent deep leaching, and high clay accumulation. A major problem associated with the Sangamon soil is its diachronous upper and lower boundaries (Follmer, 1978, 1982, 1983). To further confuse the time element, the lower 1-2 m (3.3-6.6 ft) of the early Wisconsinan loess is typically weathered and forms a pedological continuum with the underlying Sangamon soil (Follmer, 1983), and early investigators mistakenly included the former in the Sangamon profile. The Sangamon should be considered a pedocomplex rather than a single soil which developed under a unique environmental condition (Schultz and Tanner, 1957; Fredlund et al., 1985; Morrison, 1987). It apparently represents two or more paleosols welded together to form a complex that reflects significant spatial and temporal variation in environmental conditions and an appreciable time span. Although laboratory data from exposures in central Kansas indicate the Sangamon soil was strongly weathered chemically, presumably under a warm, moist climate (Feng, 1991), recent data from the Eustis ash pit in south-central Nebraska indicate that the Sangamon soil is not very mature geochemically (Muhs and Johnson, 1996).

Because of apparent time transgressiveness, the age of the Sangamon soil is not precisely known. Follmer (1983) reported a radiocarbon age of 41,700±1100 yr B.P. on plant material from the top of the Sangamon in its type area in Illinois. Forman (1990a) reported TL ages of 140±20 and 70±10 ka from loess below the Sangamon soil at two separate sites in Iowa and Illinois, and concluded the Sangamon soil is diachronous and may consist of multiple soils. Feng (1991) and Feng and others (1994) reported a TL age of about 70 ka in the lowermost part of the Sangamon soil exposed in central Kansas and associate it with marine isotope stage 3. Although Richmond and Fullerton (1986b) assigned Sangamon time to 132-122 ka (isotope substage 5e), they acknowledged reported ages (relative and absolute) ranging from early Illinoian to middle Wisconsin. Basal ages on the overlying Gilman Canyon Formation from numerous locations in Kansas and Nebraska (Johnson, 1993a, b) provide a minimum age of about 45 ka for the Sangamon soil. Also, Forman (1990b) and Forman and others (1992) obtained TL and radiocarbon ages of 35-30 ka within the loess overlying the Sangamon soil at the Loveland paratype section in Iowa and the Pleasant Grove School section in Illinois.

Fort Riley. Thus far, investigations on the reservation have indicated that Illinoian age sediments are ubiquitous but relatively thin, and expressed primarily as the Sangamon soil developed within them. Best known expression of the Sangamon soil occurred at the Sumner Hill locality in a thin layer of Loveland loess overlying alluvium.

Wisconsinan Stage

Stratigraphy associated with the Wisconsinan glacial period in the central Great Plains consists of two loess units and associated soils: Gilman Canyon Formation and Peoria loess.

Gilman Canyon Formation. The Gilman Canyon Formation, first recognized in Nebraska (Reed and Dreeszen, 1965), is a middle to early-late Wisconsinan (cf. Farmdalian) loess. Equivalents of the formation have been recognized elsewhere: the Loveland loess is buried by the Roxana silt from Minnesota and Wisconsin to Arkansas and by the Pisgah Formation in western Iowa (Bettis, 1990). The Gilman Canyon of Nebraska and Kansas is typically dark in color, silty, leached of calcium carbonate, and heavily enriched in organic carbon via pedogenesis (melanization). As noted above, the formation was once considered to be the attenuated A horizon of the Sangamon soil (Thorpe et al., 1951; Reed and Dreeszen, 1965).

Reed and Dreeszen (1965) provide limited textural data and description of the Gilman Canyon Formation at the type section. Their description within the columnar section at the Buzzard's Roost exposures states (p. 62): “Upper 12 inches [31 cm] is medium dark gray, slightly humic, silt; middle 1 foot 1 inch [33 cm] is light brownish-gray silt; basal 3 feet 8 inches [1.12 m] is dark brownish-gray, humic, soil-like silt; entire thickness is noncalcareous … 5 feet 9 inches [1.75 m]." Although all of these attributes described at the type section appear representative of the formation as observed in Nebraska and Kansas, the bimodal distribution of humus is curious: this suggests the existence of two periods of relative stability, or low accumulation rates, and an intervening period of accelerated accumulation rates. Consequently, the Gilman Canyon Formation often appears as one or more cumulic A horizons that are developed within a variably to noncalcareous loess, usually no more than 1.2 m thick. In a section revealing an expanded valley phase of the Gilman Canyon Formation, May and Souders (1988) recognized three distinct organic zones, each of which may represent a separate episode of pedogenesis. Two such zones have been recently observed by the author at the Eustis ash pit in south-central Nebraska. If two or more distinct periods of soil formation did indeed occur regionally, they are obscured at many localities, likely due to bioturbation. Overall, the formation reflects a sufficiently slow rate of loess fall (<0.08 mm/yr) such that pedogenesis was operating more or less continuously, but with a decreased intensity at one or more times.

As expressed, the Gilman Canyon Formation is frequently overlain by 0.9-1.5 m of leached loess which is considered to be basal Peoria Formation. Correlative with the Gilman Canyon and overlying leached loess zone is the Citellus zone (a ground squirrel now recognized as the genus Spermophilus) of Nebraska (Condra and Reed, 1950). The leached zone is transitional between the well developed A horizon(s) in the Gilman Canyon and the calcareous Peoria loess above, and probably reflects a sufficiently slow accumulation of Peoria loess such that pedogenesis could keep pace only partially. A.B. Leonard (1951, 1952) supported the contention that the leached, or basal zone was slowly accumulating, early Peoria loess experiencing pedogenesis through inference that gastropods were originally present, but subsequently destroyed during weathering of the loess. Above the leached zone, the rate of accumulation of Peoria loess was sufficiently rapid (c. 0.6mm/yr) as to preclude any soil development.

Radiocarbon ages from the Gilman Canyon Formation range from approximately 40 ka at the base to 20 ka at the top (May and Souders, 1988; Johnson et al., 1993a). The basal age of 40 ka agrees well with the time set by Richmond and Fullerton (1986a) for the beginning of the late Wisconsin. While Nebraska has many dated locations forming an arcuate pattern around the eastern and southern sides of the Sand Hills, data from Kansas are relatively limited. The ages in Kansas do show, however, good agreement from the south-central to the north-central part of the state and with those from Nebraska.

Given the radiocarbon time control and stratigraphic information currently available for the Gilman Canyon Formation within Kansas and Nebraska, it appears that the associated soil is a geosol, i.e. a laterally traceable, mappable, pedostratigraphic unit with a consistent time-stratigraphic position (Morrison, 1965; North American Commission on Stratigraphic Nomenclature, 1983, p. 865). The entire formation may be considered a geosol, but, because of the possibility for the existence of two or more identifiable cumulic A horizons merged or welded together, it may ultimately be considered a composite geosol. On Fort Riley, the Gilman Canyon Formation is typically welded to the Sangamon soil below and to the Brady soil above.

Peoria loess. Leverett (1899) first proposed the name Peoria for an interglacial period between the Iowan and Wisconsin glacial stages. When Alden and Leighton (1917) demonstrated the Peoria was younger than Iowan, usage shifted to that of a loess, rather than a weathering interval. Within the Midcontinent, several names have been used for post-Farmdalian loess. Ruhe (1983) prefers to use the term "late Wisconsin loess" because of the uncertainties in stratigraphic equivalency from one region to another. The Peoria Formation is typically an eolian, calcareous, massive, light yellowish-brown silt that typically overlies the Loveland Formation or an approximate equivalent of the Gilman Canyon Formation.

Ruhe (1983) notes three major features of late-Wisconsinan (Peoria) loess: it thins downwind from the source area, decreases in particle size systematically away from the source area, and is strongly time-transgressive at its base. The latter feature is unresolved and results in correlation problems. Ruhe (1969) realized a decrease in the age of the soil under the loess from 24,500 yr BP near the Missouri River to about 19,000 yr BP eastward across southwestern Iowa. A decrease from 25,000 to 21,000 yr BP was noted for the base of the loess along a transect in Illinois (Kleiss and Fehrenbacher, 1973). The top of the loess also seems to be time-transgressive, ranging from about 12,500 yr BP in Illinois (McKay, 1979b) to 14,000 yr B.P. in central Iowa (Ruhe, 1969).

In Kansas, the Peoria is a reddish, yellowish, or tan buff color, homogeneous, massive, locally fossiliferous, variably calcareous, and ranges from coarse silt and very fine sand to medium to fine silt and clay (Frye and Leonard, 1952). Thicknesses vary from in excess of 30 m adjacent to the Missouri River valley to 0.6 m in discontinuous patches. Any accumulation less than 0.6 m is presumed unrecognizable in the field because it has become incorporated into the existing surface soil. Peoria loess typically rests conformably upon the Gilman Canyon Formation.

Despite the amount of attention given Peoria loess in Kansas, the source of the silt is not completely certain. Upon a review of the available data, Welch and Hale (1987) conclude that a single source was not likely for all loess deposits in Kansas, and that the loess was derived from a combination of three sources: glacial outwash river flood plains, present sand dune areas, and fluvial and eolian erosion of the Ogallala Formation. Research on trace element concentrations in loess (Johnson and Muhs, 1996) indicates, however, that the Platte River valley was the primary source, with secondary inputs from the major river valleys to the south (e.g., Republican, Smoky Hill, Solomon, Arkansas).

Although readily visible stratigraphic breaks such as the Jules soil recognized in Illinois (Frye and Willman, 1973; Frye et al., 1974; Ruhe, 1976; McKay, 1979a, b) and the soil zones in Iowa (Daniels et al., 1960; Ruhe et al., 1971) have not yet been identified in

Kansas and adjacent Nebraska, evidence of one or more stable or vegetated surfaces is common. The only indication of soil development recognized is that of a Bt horizon in the Medicine Creek valley (May and Holen, 1993); interestingly, the soil has a probable Paleoindian association (May, 1991). The most common line of evidence for a discontinuity(ies) in Peoria loess deposition is that of plant remains, usually outcropping as lenses. Many of the age determinations were made from Picea remains, indicating a cool, moist environment. Although radiocarbon data document the burial of vegetative material throughout the Woodfordian, two temporal clusters or modes of ages appear from the limited data: one 18-17 ka and another 14-13 ka. The former time interval represents the last glacial maximum and the latter the time of major deglaciation (Ruddiman, 1987). Interpreting ice core data from Greenland, Paterson and Hammer (1987) record a dramatic decrease in atmospheric dust content from about 13,000; this period of reduced atmospheric dust may relate to the time of relative surface stability and tree establishment. Regional geomorphic data also support the existence of a hiatus at this time. May (1989), identifies deposition of the Todd Valley Formation in the South Loup River of central Nebraska at about 14 ka, which is subsequently buried by loess. Further, Martin (1990) identifies entrenchment in the Republican River of south-central Nebraska at about 13 ka, after which valleys were filled with late Peoria Loess.

Fort Riley. The Gilman Canyon Formation sediments and soil were present at all sites sampled for magnetic and isotopic analyses, indicating that the formation has both upland (loess) and valley (alluvium) phases preserved at Fort Riley, as elsewhere in the region. Radiocarbon ages on the formation range from about 19ka to over 23ka. These relatively young ages represent the most recent period of Gilman Canyon time pedogenesis; the relatively unaltered loess and alluvium was not sampled for dating. Coring and backhoe trenching indicates that Peoria loess is typically relatively thin, except along the bluffs of the Kansas River valley, where it reaches thicknesses often or more meters.

Holocene Series

The transition from the late Pleistocene into the Holocene, about 10 ka (Hopkins, 1975), was a time of dramatic environmental change and attendant stratigraphic discontinuities. A major feature in the loessal stratigraphic record is a well developed soil, the Brady. Approximately 9,000 years ago, the uplands again destabilized with the renewed influx of loess, which continued episodically throughout the Holocene. Holocene loess is termed the Bignell throughout the central Great Plains.

Brady soil. The Brady soil was first named and described by Schultz and Stout (1948) at the Bignell Hill type locality, an eolian sequence exposed along a road cut in the south valley wall of the Platte River of western Nebraska. The soil is developed within the Peoria loess and is overlain by the Bignell loess. The name was subsequently adopted by researchers in Kansas (Frye and Fent, 1947; Frye and Leonard, 1949, 1951). It is regionally extensive only in the northwestern and west central parts of Kansas, and even there it occurs discontinuously on the landscape. Frye and Leonard (1951) and Caspall (1970, 1972) recognized Brady development in northeastern and other parts of Kansas. Without the overlying Bignell loess, the Brady soil does not exist; the modern surface soil has incorporated post-Bradyan loess fall into its profile or may have developed in Peoria loess subsequent to the erosion of the Brady soil and Bignell loess. The Brady soil is typically dark gray to gray-brown and better developed than the overlying surface soil within the Bignell loess. Strong textural B horizon development and carbonate accumulation in the C horizon are typical, although it occasionally displays evidence of having formed under poorer drainage conditions than have associated surface soils (Frye and Leonard, 1951). Feng (1991) noted that the Brady soil, as expressed in Barton County, is strongly weathered both physically and chemically.

The Brady is the first major geosol to occur in the stratigraphic record of the region since the Gilman Canyon soil 10,000 years earlier. Still, its age had been uncertain, even at the type locality, until recently. Dreeszen (1970, p. 19) reported a radiocarbon age of 9160±250 (W-234) obtained in 1954 and another in 1965 of 9750±300 (W-1676), both from the type section but very likely contaminated by modem plant roots. Subsequently, Lutenegger (1985) reported an age of 8080±180 yr BP but provided no specifics other than that the source was the A horizon of the Brady soil at the type section. Better age control for the type section has since been secured by this investigator: radiocarbon ages of 9,240±110 (Tx-7425) and 10,670±130 (Tx-7358) yr BP were obtained on the upper and lower 5 cm, respectively, of the Brady A horizon.

The Brady soil has been recently dated at localities in Nebraska and Kansas. Souders and Kuzila (1990) obtained a radiocarbon age of 10,130±140 yr BP on the Brady soil occurring within the Republican River valley of south-central Nebraska. Sites along Harlan County Lake upstream from Naponee have yielded a number of ages, ranging from 10,550±160 to 9,020±95 yr BP, on exposures of the Brady soil (Cornwell, 1987; Johnson, 1989; Martin, 1990; Martin and Johnson, 1995). Two radiocarbon ages of 9820±110 (TX-7045) and 10,550±150 (TX-7046) yr BP have been derived from the upper and lower 5 em, respectively, of the Brady A horizon exposed in Barton County, central Kansas (Feng, 1991).

Although it appears Brady pedogenesis occurred from about 10,500 to as recently as 8,500 yr BP, greater refinement of the Brady soil chronology is necessary, but present data clearly indicate it was a product of a major period of landscape stability at a time when widespread climatic shifts were occurring at the end of the Wisconsin. This was the first significant period of soil development since Gilman Canyon time, and represents the climate of the early Holocene. There is an isochronous alluvial soil found throughout the region which is particularly well expressed within the Kansas River basin (Johnson and Martin, 1987; Johnson and Logan, 1990). The two ages of 8,274±500 (C-108a) and 9,880±670 (C-471) yr BP determined from alluvial fill (Fill-2A) at archaeological sites Ft-50 and Ft-41 on Harry Strunk Lake in southwestern Nebraska (Schultz et al., 1951; Libby, 1955) were the first radiocarbon determinations on the Brady soil. The soil, occurring in both eolian and alluvial contexts, appears to qualify, based upon present radiocarbon data, as a *geosol*, like the Gilman Canyon Formation soil. Collectively, age data indicate a soil forming interval that lasted for 1,500 to 2,000 years.

Development of the Brady soil correlates well with indicators of regional climatic change. The fossil pollen record at Muscotah Marsh of northeastern Kansas indicates that spruce had essentially disappeared from the region by about 10,500 yr BP. As this decline occurred, deciduous tree species increased until about 9,000 years B.P., the time at which grassland expansion began (Grüger, 1973). On a hemispheric scale, the abrupt decrease in atmospheric dust noted in the Greenland ice core at 10,750 yr BP (Paterson and Hammer, 1987) reflects decreased loess deposition and possibly Brady-age pedogenesis associated with relative terrestrial stability. Further, 18O levels within the same core suggest rapid warming about 10,750 yr BP, with the characteristic Holocene temperature regime being established about 9,000 yr BP.

Bignell loess. The Bignell loess was first described and named at the type locality in a bluff exposure on the south side of the Platte River valley southeast of North Platte, Nebraska (Schultz and Stout, 1945). It is typically a gray or yellow-tan, massive silt, calcareous and seldom more than 1.5 m (5 ft) thick. Although it is often somewhat less compact and more friable than the underlying Peoria loess, no certain identification can be made without the presence of the Brady soil. The Bignell loess does not form a continuous mantle on the Peoria; instead, it occurs as discontinuous deposits which are most prevalent and thickest adjacent to modem-day valleys, particularly the south side, and often within depressions on the Peoria surface. Feng (1991) speculates that the Bignell loess of central Kansas is relatively well weathered because it was derived from a pre-weathered source, the Brady soil surface, perhaps eolian and alluvial phases alike. This is consistent with the earlier interpretation derived in Nebraska that Bignell loess is at least partially comprised of re-worked Peoria loess (Condra et al., 1947, p. 33).

It appears from the radiocarbon ages obtained at the type section in Nebraska and the Speed road cut in northwestern Kansas that the Bignell loess can be no older than 8,000 to 9,000 yr BP Snails collected by A.B. Leonard from the lower part of the Bignell in Doniphan County, northeastern Kansas, produced ages of 12,500±400 (W-231) and 12,700±300 (W-233) yr BP (Frye and Leonard, 1965). Because the shell material had absorbed an indeterminate amount of dead carbonate, Frye and others (1968) proposed an averaged age of approximately 11,000 years. Based upon the age data available for the Brady, the soil humate-derived ages are probably closest to reality.

Fort Riley. The Brady soil and Bignell loess are prominent elements of the late-Quaternary stratigraphy on the reservation. Together with the surface soil, they typically comprise the approximately upper 2 m of most sites documented (D.L. Johnson, 1996), including the loess sites references in this report. Therefore, it appears that appreciable loess was deposited during the Holocene. This is not surprising given the proximal juncture of two large stream systems, which formed a significant loess source (dust from a relatively wide valley floor), and the situation of the sites on the north side of the river valley with prevailing southerly winds.

Regional Late-Quaternary Alluvial Stratigraphy

Late-Quaternary alluvium is ubiquitous throughout the installation and is the primary focus of the Fort Riley geoarchaeological investigations due to the concentration of surficial and buried cultural material. Alluvial deposits recognized thus far on the installation date to the last glacial period (Fig. 2).

Late-Wisconsinan Stage

Much of the chronology of late-Wisconsinan landform evolution for the region was compiled in the 1940s and early 1950s, prior to the use of radiocarbon dating (e.g., Lugn, 1935; Schultz and Stout, 1945; Frye and Leonard, 1951), and focused to a large degree on the upland rather than valley deposits. Additionally, erosion has removed a large part of late-Quaternary record from most drainage basins in the central Great Plains (Knox, 1983). Accordingly, a comprehensive sedimentation and erosion chronology for the region during the late Wisconsin is lacking.

It is becoming increasingly apparent that entrenchment occurred in the channels of the Kansas River basin sometime during the late Wisconsin. A basal soil buried within the fill of both tributary and major stream valleys of the Kansas River basin has an age of 10,500-10,000 yr BP (Johnson and Martin, 1987; Johnson and Logan, 1990), thereby providing a minimum age on the entrenchment. May (1989) has radiocarbon dated the Todd valley fluvial sand of central Nebraska to about 14,000 years B.P., although Condra et al. (1950) had postulated a much earlier Wisconsinan age. Martin (1990; 1993) recognized a late-Wisconsin fill in the Republican River valley that was largely removed through entrenchment about 13,000 yr BP. A radiocarbon age of 14,700 yr BP was obtained on spruce wood situated above cross bedded fluvial sand and gravel at the North Cove site located in that same reach of the Republican River valley (Wells and Stewart, 1987; Johnson, 1989). At the Prairie Dog Bay site in the Republican River valley, the stratigraphy and radiocarbon ages suggest down cutting before 11,800 yr BP (Martin, 1990, 1993). Speculation about the cause of this entrenchment centers on an increase in effective moisture as climatic conditions ameliorated towards the end of the Pleistocene. Spring deposits dating to this time at the North Cove site possibly formed during the increase in moisture (Johnson, 1989; Martin, 1990).

Brice (1964) studied alluvial fills and terraces in the valleys of the North Loup, Middle Loup, and South Loup rivers of central Nebraska, and identified two major terraces in the Loup valleys. The Kilgore terrace occurs as remnants 26 to 30m above stream level along the South Loup River. Brice suggested that valley fill underlying the Kilgore terrace is Peorian (late Wisconsin) in age. The adjacent Elba Terrace, which stands 11 to 12 m above stream level, is the most prominent and extensive terrace in the main valleys and is primarily of Holocene age.

Holocene Series

During the last decade, a great deal of attention has been focused on the development of alluvial chronologies in the central Great Plains, typically in connection with geoarchaeological investigations. As a consequence, this research has resulted in a number of studies and a sizable radiocarbon data base; well over 400 radiocarbon ages have been obtained from alluvium in Kansas and Nebraska (Johnson et al., 1996). Only a sampling of the many studies is presented below.

Much of the research in Nebraska has focused on the Loup River basin. Brice (1964) recognized two major terrace systems in the basin and obtained early Holocene radiocarbon ages of 10,500, 9,000, and 8,500 yr BP on fill beneath the lower of these terraces, the Elba. In a recent re-examination of the Elba terrace, May (1990, 1991) secured radiocarbon ages ranging from nearly 11,000 to 4,670 yr BP from the Cooper's Canyon area. On the South Loup River, May (1986, 1989, 1992) recognized four alluvial fills, with the oldest one dating between about 10,200 and 4,700 years B.P., thereby correlating temporally with the Elba terrace of the North Loup. Elsewhere in the basin, Ahlbrandt and others (1983) dated organic accumulations in alluvial sands at 8,410 yr BP from a site on the Dismal River.

In the Kansas River basin, alluvial geomorphic studies have a relatively long history, beginning in the 1950s. The first dating of alluvial stratigraphy on the Kansas River proper was done by Holien (1982), who obtained an age of 10,450 yr BP on a soil buried within lower Newman terrace fill at the Bonner Spring site. Subsequent radiocarbon dating of Newman fill at this locality (Johnson and Martin, 1987; Johnson and Logan, 1990) and others (Bowman, 1985) produced more early Holocene ages. The lower Holliday terrace has dated about 4,300 yr BP and younger (Johnson and Logan, 1990).

Many studies have been conducted elsewhere in the Kansas River basin on the many tributaries. Some of the first radiocarbon dating was carried out on samples collected from the Republican River basin by Schultz and others (1948): from varied locations they secured early to middle Holocene ages from buried soils. The most recent research in the basin was conducted by Martin (1990, 1992) who concluded from dating various alluvial fills that the majority of the fill was deposited less than about 4,600 yr BP.

Several geoarchaeological studies were done in conjunction with cultural resource management projects focusing on federal impoundments within the Kansas River basin. Mandel (1987) in a study of the lower Wakarusa River recognized two terraces, the lower of which produced radiocarbon ages of about 2,900 yr BP and less. A study of the alluvial history of the Smoky Hill River in the vicinity of Kanopolis Lake (Mandel, 1988, 1992) revealed a striking absence of early and middle Holocene fill in small valleys, and middle Holocene fill in the main valleys and in alluvial fans.

In their study of Wolf Creek basin, Kansas, Arbogast and Johnson (1994) observed that alluviation of early-Holocene flood plains in this small basin was episodic, with at least one period of flood plain stability and soil formation about 6,800 yr BP. During the middle Holocene (ca. 6,500-5,300 yr BP), lateral erosion and entrenchment flushed most early-Holocene fill from the main valley ofWolf Creek and the lower reaches of its larger tributaries. Fallowing the interval of mid-Holocene erosion, sediment accumulated on flood plains between 5,300 and 3,000 yr BP. Late Holocene alluviation was episodic, with intervening periods of flood plain stability and soil formation about 1,800, 1,500, and 1,200 yr BP.

A number of studies have been conducted in the Arkansas River basin area of south-central and southeastern Kansas. Mandel examined terraces and associated fills in the Neosho (Mandel, 1989, 1992, 1993) and Verdigris Rivers (Mandel, 1993), obtaining radiocarbon ages on fill to about 4,200 yr BP. The most extensive study in the Arkansas River basin was that of the Pawnee River basin by Mandel (1988, 1991, 1994). Two terraces were recognized in the higher order tributaries, with fill of the high terrace dating between about 10,000 and 5,000 yr BP, and that of the low terrace to 3,000 yr BP and younger. Of the three terraces present in the lower part of the system, the lowermost one has Holocene fill and the others are Pleistocene. Holocene valley fills in the Pawnee Basin appear to lack soil development from about 7,000 to 5,000 yr BP.

The alluvial record is temporally and spatially fragmented, i.e., the history of valley and stream evolution stored in alluvium is scattered and wrought with gaps. So, it is only by assembling this fragmentary information that one obtains a unified perspective on the record of stream evolution. Out of the many studies conducted in recent years, a pattern of change is emerging. Large stream valleys appear to contain, more or less, alluvial fill dating throughout the Holocene, whereas small stream valleys typically contain only fill dating in the late Holocene. This model has an intuitive basis in that the probability of survival of early and middle Holocene fill in smaller streams is greatly diminished by the limited storage capacity for alluvium and the relatively high stream gradients, large area in hillslope, and associated peaked flood waves. Exceptions to this pattern do, of course, exist (e.g., Lime Creek, Nebraska: May, 1996; Wolf Creek: Arbogast and Johnson, 1994), but are likely due to locally unusual valley width and other discernible factors.

A first approximation of this alluvial model was presented by Johnson and Martin (1987) in an examination of radiocarbon ages obtained from alluvial fill in the central Great Plains. In recent years, the model has evolved with a vastly expanded data base and been articulated recently by Mandel (1995). He noted that fill in small valleys appears to be less than 4,000 years old, and that the missing early and middle-Holocene record is frequently preserved at the lower end of small stream valleys as terrace fill or alluvial fans.

From the alluvial chronologies, it is obvious that regional synchroneity of stream behavior exists in the central Great Plains (Johnson and Martin, 1987; Johnson and Logan, 1990; Mandel, 1995). When erosion and sedimentation are considered in a stream hierarchical sense, patterns of coincidence appear, such as similar times of flood-plain stability and attendant soil formation. A frequency distribution of over 400 radiocarbon ages from alluvium of Kansas and Nebraska) provides an indication of the synchroneity. The high frequencies of the last 5,000 years reflect the age of the alluvium in large and small streams, whereas those prior to about 8,000 represent the ages from the large valleys alone. Alluvial fans ages account for many ages within the 4,000 to 8,000 year range (Mandel, 1995). The greatest frequency of ages occurs about 1,200 yr BP, a time when pronounced low terrace stability and soil development occurred throughout the stream systems. Another notable feature of the distribution is that when the ages obtained from alluvial fans are not considered, very few alluvial ages fall within the 5,000 to 7000 yr BP period. This paucity of ages suggests little flood-plain stability and/or preservation of alluvium from that interval, which coincides with the Altithermal climatic episode. Stream activity of this dry period may have been characterized by rapid sedimentation, thereby precluding soil development, in response to low-frequency, high-intensity convectional storms (Knox, 1976, 1983).

Regional synchrony in Holocene fluvial behavior suggests that climatic fluctuation is the dominant external variable in stream systems (Wendland, 1982; Knox, 1976, 1983). Changes in climate during the Holocene were frequent and episodic (e.g., Wendland and Bryson, 1974; Kutzbach, 1985; COHMAP members, 1988), resulting in discrete periods of stream stability and instability (Knox, 1983).

The concept of a middle Holocene, or Altithermal (ca. 7,000-5,000 yr BP) cultural hiatus on the Great Plains has become well-entrenched within the archaeological literatures. Of the various theories put forth to explain the hiatus (Reeves, 1973), fluvial erosion or aggradation sufficient to dramatically alter the record for the region during the interval 7,000-5,000 yr BP is most pertinent (Johnson, 1987; Mandel, 1995). Some argued that the similarity in the alluvial stratigraphic record from eastern humid portions of the region to the more arid western areas, as well as with chronologies further afield indicates that regionally anomalous erosion and deposition do not explain the hiatus completely; rather, the increased dryness during the Altithermal was likely sufficient to reduce populations on the Plains (Wedel, 1961; Knox, 1978; Wendland, 1978). However, the rapidly expanding alluvial radiocarbon and stratigraphic data base for the region is indicating that much of the cultural record, namely that of the Archaic period, is buried, often deeply, or lost to erosion.

Paleoclimatic History of the Wisconsinan and Holocene

As the most recent glacial episode, the Wisconsin has the greatest chronostratigraphic resolution. However, existing knowledge of the climatic environment for this time interval is relatively limited and inconsistent for the central Great Plains. To date, either pollen records from peripheral areas or synthesis of various types of proxy data have been used to reconstruct climate history of the region.

The insolation record exhibits two relatively warm peaks (c. 50 and 30 ka) during marine isotope stage 3. Each peak is followed by a relatively minor and gradual decrease, culminating in the decrease to the glacial maximum (c. 18ka). In contrast to the gradual insolation changes, most paleoclimatic records from this interval indicate rapid alternations of warm and cold events, which in frequency and timing appear to be unrelated to the Milankovitch forcing (Curry and Follmer, 1992). Dansgaard and others (1985) showed that rapid and extreme fluctuations in stable isotopes (signifying air-temperature differences of 5° C) from two sites in Greenland appear to correlate over the past 50,000 years . These fluctuations are in phase with changes in CO_2 and dust content. Rapid and substantial temperature fluctuations recorded in ice core segments during stage 3 also correspond with oscillations in the North Atlantic marine sediment record of species abundance and ice rafting (Heinrich, 1988). Using accelerator 14C ages on a planktonic polar species, Broecker and others (1988) identified four rapid climatic oscillation between 40 and 22 ka in the North Atlantic.

The regional upland vegetation, as inferred from the pollen record from Cheyenne Bottom in Kansas (Fredlund, 1995), appears to have been nearly treeless throughout the Farmdalian (ca. 30-24 ka). The pollen record suggests that, although regional tree and shrub populations were higher and more diverse than in Holocene, they were a secondary component of the overall vegetative structure. Grassland-sage steppe dominated the regional uplands surrounding the Cheyenne Bottoms basin throughout the Farmdalian period. The rise in Cheno-Am pollen percentages and an influx of sand beginning at about 25 ka probably mark the rapid onset of a cycle of aridity. Immediately after the onset of aridity, the most noticeable changes are declining percentages in the Cheno-Am types and rising percentages of *Pinus*. The increase in *Picea* and other arboreal pollen may signal a climatic shift toward cooler climatic conditions at ca. 24 ka. Unfortunately, the Woodfordian substage of the Wisconsin is missing from the Cheyenne Bottoms record.

Limiting radiocarbon dates in North America indicate that glaciation commenced about 25-27 ka and thus allow less than 10,000 years for ice buildup prior to 18 ka (Andrews, 1987). The structure of deglaciation is uncertain. There is evidence supporting: (1) a smooth deglaciation model with fastest ice wastage centered on 11 ka; (2) a two-step deglaciation model with rapid ice wasting from 14 to 12 ka and 10 to 7 ka, and a mid-deglacial pause with little or no ice disintegration from 12 to 10 ka; and (3) a Younger Dryas deglaciation model with two rapid deglacial steps as in (2) above, interrupted by a mid-deglacial reversal with significant ice growth from 11 to 10 ka.

The data supporting the smooth deglaciation model are maps of Laurentide ice area based on radiocarbon-dated glacial deposits (Andrews, 1987). Although there are subtle suggestions of more rapid retreat at or near the time of the two steps mentioned above, these curves indicate a steady progressive retreat of North America ice, with significant oscillations in retreat rate only at local spatial scales. Some marine $\partial^{18}O$ curves also show a smooth progressive decrease toward Holocene values.

The step deglaciation model is also supported by some marine $\partial^{18}O$ records (Mix, 1987). In addition, the distinctive patterns of change in sea-surface temperature of the North Atlantic Ocean and in Greenland ice-core $\partial^{18}O$ values also show abrupt step-like warmings at 10 ka and about 13 ka; these warmings might be associated with step-like decreases in Laurentide ice volume. Regionally integrated rates of pollen change in eastern and central North America also show a rapid change in centered on 13.7 and 12.3 ka. (Ruddimann, 1987).

The Younger Dryas (e.g., Osborn et al., 1995: Bard et al., 1993; Peteet et al., 1992) deglaciation model is suggested by the strong signal of sea-surface temperature cooling between 11 and 10 ka in the North Atlantic Ocean. At least early and perhaps all of Brady pedogenesis coincides with an abrupt and brief cool interval correlative with the classic Younger Dryas cold interval of the North Atlantic region.

By the middle Holocene, drying had reached a maximum according to most studies. Northwest Texas was experiencing conditions of maximum temperatures, minimum precipitation, and eolian activity between 6000 and 4500 years B.P. (Holliday et al., 1983; Holliday, 1985; 1989; Johnson, 1987; Pierce, 1987). This episode coincides with $\partial^{13}C$ values from soil organic matter from the same area revealing a shift from -23‰ in the early Holocene to -15‰ in the middle Holocene (Haas et al., 1986). These results were interpreted to represent a shift from cool-season C_3 grasses to warm-season C_4 grasses. Based on enriched $\partial^{13}C$ values in soil carbonate from northwest Texas, Humphrey and Ferring (1994) also show a middle Holocene xeric episode, although the $\partial^{18}O$ values from these same carbonates do not indicate a significant temperature change.

A noticeable shift back to cooler and/or wetter conditions was detected in many areas shortly after 5000 yr BP. The Great Bend Sand Prairie transformed to conditions much like present (Arbogast, 1995). According to Humphrey and Ferring (1994), the return to mesic conditions after 5000 yr BP was interrupted in north-central Texas by a brief warming and drying episode between 2000 and 1000 yr BP. Based on depositional environments, they concluded that cooler and wetter conditions returned after 1000 yr BP.

Methods

Task One: Two-Dimensional Landscape Evolution Model

Two objectives were involved in this task of two-dimensional mapping: (1) continue high-resolution mapping of the alluvial landscape; (2) refine the soils map of the installation to render soils-geomorphic mapping in a realistic fashion; (3) digitize the drainage system of the entire installation with field verification using high-resolution GPS; (4) continue mapping the loess distribution; and (5) map the other discrete landforms of the installation.

Alluvial landscape mapping

Procedures employed included (1) mapping alluvial landforms using stereoscopic coverage of black and white aerial photography; (2) foot survey of each accessible valley in order to refine the reconnaissance maps, (3) a second foot survey of each valley from the channel bed or water's side to correlate fills exposed in channel banks with their overlying surfaces, and to search for exposed sections worthy of documentation and, in some instances, radiocarbon dating; and (4) exploration of the unexposed valley fills using motorized, trailer-mounted coring machines with a 25-m maximum reach, and using hand augering and coring devices.

Soils map refinement

Exiting available digitized soils data for the base are of poor quality due to mismapping in the field and to imprecise electronic rendering. The Natural Resources and Conservation Service (NRCS) electronic soils maps, available from Data Access and Support Center (DASC), Kansas Geological Survey are, unfortunately, of average to poor quality for Fort Riley: in an attempt to combine different soil phases into a single soil series, the developers of the electronic database have often crossed series and grouped unrelated soils into associations. As a result, the soils map exhibits some unusual and unnatural patterns. Hence, a great deal of project time was used to make correction and modifications to the soils map through field checking and remapping and to modification of existing electronic files. The importance of doing this was that much of the mapping of landforms and deposits is dependent upon accurate soils mapping, i.e., soils-geomorphic mapping.

Digitizing and ground-truthing the drainage network

Another time-consuming but necessary activity was that of developing an accurate and realistic electronic rendering of the drainage system of the base. This was necessary for the accurate mapping of the alluvial units. Existing large-scale maps available from the installation are of relatively high quality but have become dated due to stream channel and landscape modification and to natural processes such as channel meandering and avulsing. Adjustments and refinements of the drainage system were carried out through

(1) digitization of the stream network for the entire base; and (2) field checking and ground-truthing of selected stream segments and confluences using high-resolution GPS (Trimble system). Additionally, some GPS assistance was provided by installation personnel. The final product is a detailed digital elevation model of the installation.

Loess distribution

Because of the size and restricted access to much of the installation, loess distribution was initially mapped using the updated soils map for the installation. After mapping the older loesses (the Loveland and Peoria loesses), the Distribution of the Bignell loess was determined because of its importance in the preservation of the archaeological record. The distribution of the Bignell loess was determined through coring, trenching, and topographic interpretation, whereas the electronic map was relied upon for distribution of the Peoria and Loveland loesses.

Other discrete landforms

Because other landform units exist on the installation and exhibit archaeological importance, they were mapping using both aerial photography and field survey. Other landform units mapped are colluvium, or slope deposits; alluvial fans, which merge into the valley terrace and flood plain fill; and bedrock outcrops. Bedrock areas included vertical and near-vertical non-alluvial landscapes and tracts where no significant loess covering exits, only a shallow surficial soil.

Task Two: Development of a Computerized ACCESS database of “Dig Permit” Data

It was not possible to conduct this particular task due to a lack of dig permit data records. This was due to the fact that the government was unable during the contract period to provide the principle investigator with the paper hardcopy records as specified in item 4 of the statement of work in the schedule of supplies/service.

Task Three: Three-Dimensional Visualization of Landform Sediment Assemblages

Subsurface alluvial stratigraphic data collected during the course of previous investigations and two dimensional mapping of the alluvial surfaces was used to develop 3-D visualizations of the valley bottom topography on the installation. In accordance with the contract, ESRI ArcView 3-D Analyst software was employed to render these views of the valley fills. The objective in providing this perspective is one of illustrating the range in topography and the implicit range in ages and the depth to which cultural materials may be buried and thereby exposed to disturbance by military training. Other software and databases were used to generate three-dimensional, low-oblique perspectives on the study basins.

Task Four: Preparation of a Comprehensive Report

This document represents the first draft report of research outlined under this contract. Five copies of the final report shall be submitted with an accompanying Iomega-brand Zip disk containing all text, data and ESRI software (ArcView/ArciNFO) project files.

Results

Task One: Two-Dimensional Landscape Evolution Model

Distribution and ages of alluvial fills

Under this contract, the mapping of alluvial fill was expanded in aerial extent and refined for those areas mapped previously. Alluvial landforms of drainages located along the southern and northeastern periphery of the central firing range have been mapped and in most instances radiocarbon dated. Alluvial surfaces of Breakneck, Pumphouse, Onemile, Forsyth, and Wildcat creeks have been mapped. Further, radiocarbon age control has been obtained on Pumphouse, Forsyth, lower Threemile and Sevenmile (south of the firing range), and Wildcat creeks, as well as on the Kansas and Republican rivers along the southern boundary of the base (Table 1).

Table 1. Valley (Alluvial) Radiocarbon Ages

Site Name (no.)	Depth (cm)	Material Assayed	ISGS Number	Uncorrected Age	∂13C (‰)	Corrected Age
KANSAS R.						
Airport Terrace Core 20	168	humates [1]	2623	19,900±450	-19.4	19,990±450?
Airport Terrace Core 33	30	humates	3056	2,130±140	-15.6	2,280±140
	40	humates [1]	2996	1,910±70	-14.5	2,080±70
	163	humates [1]	2997	11,480±440	-20.4	11,550±440
	193-203 a	humates	3053	14,240±480	-17.8	14,360±480
	193-203 b	humates [1]	3054	17,690±1000	-17.7	17,800±1,000
	228-233	humates	3003	13,640±540	-18.3	13,750±540
	525-528	humates	3004	11,440±570	-16.5	11,580±570
FR1	90	humates	3650	2,170±70	-15.2	2,330±70
	103	humates	3649	2,240±70	-17.2	2,360±70

Site Name (no.)	Depth (cm)	Material Assayed	ISGS Number	Uncorrected Age	∂13C (‰)	Corrected Age
FR1 (cont.)	116	humates	3648	1,320±70	-15.2	1,480±70
	136	humates	3662	1,460±70	-15.5	1,610±70
	136	humates	3662 replicate	1,500±70	-15.6	1,650±70
	173	humates	3660	2,740±70	-14.9	2,900±70
	201	humates	3658	3,680±70	-15.6	3,830±70
	275	humates	3601	4,950±80	-17.2	5,070±80
	345	humates	3734	5,950±70	-18.2	6,060±70
FR2	74	humates	3602	2,960±70	-16.0	3,100±70
	101	humates	4175	4,060±70	-16.2	4,200±70
	258	humates	3726	5,870±160	-19.6	5,960±120
	345	humates	4174	5,640±70	-18.2	5,750±70
	450	humates	4173	5,820±70	-18.6	5,920±70
FR3	290	humates	3812	7,240±70	-17.1	7,370±70
	415	humates	4064	9,400±160	-19.4	9,490±160
FRS	104	humates	3707	1,500±70	-17.2	1,630±70
	390	humates	3657	5,510±80	-18.4	5,620±80
REPUBLICAN R.						
FR10	246	humates	3597	1,380±70	-16.6	1,520±70
	310	humates	3598	1,590±70	-15.7	1,740±70
	424	humates	3599	1,880±70	-16.6	2,010±70
	510	humates	3600	3,790±110	-19.0	3,880±110
WILDCAT CR.						

Site Name (no.)	Depth (cm)	Material Assayed	ISGS Number	Uncorrected Age	∂^{13}C (‰)	Corrected Age
WC1 (FR7)	85	humates	3780	1,790±70	-16.7	1,920±70
	226	humates	3781	9,830±100	-17.0	9,960±100
	315	humates	3604	17,000±300	-22.7	17,040±300
	434	humates	3603	23,770±300	-19.2	23,860±300
	560	humates	3608	23,780±410	-18.6	23,890±410
	612	humates	3607	23,400±400	-19.2	23,500±400
WC4-T1	149	humates	4001	2,710±70	-16.3	2,850±70
	222	humates	4024	1,850±70	-19.3	1,940±70
WC4-T2	117	humates	4073	3,370±70	-15.9	3,520±70
	175	humates	4000	4,210±70	-18.6	4,310±70
	271	humates	4025	5,440±70	-16.7	5,570±70
WC4-T3	113	humates	4171	1,260±70	-18.0	1,380±70
WC5-T1	126	humates	3998	1,600±70	-16.4	1,740±70
WC5-T2	322	humates	4072	24,280±150	-16.9	24,410±150
WC5-T6	88	humates	4172	3,480±70	-13.9	3,660±70
	359	humates	4034	10,150±80	-16.0	10,290±80
FORSYTH CR.						
FR4A	86	humates	3856	1,720±70	-15.7	1,870±70
	118	humates	3617	2,850±70	-17.1	2,980±70
	380	humates	3609	6,630±70	-17.7	6,740±70
FR4B	155	humates	3871	8,510±90	-17.0	8,640±90
	167	humates	3860	8,550±70	-17.5	8,680±70
	225	humates	90902	9,600±70	-19.6	9,690±70

Site Name (no.)	Depth (cm)	Material Assayed	ISGS Number	Uncorrected Age	∂13C (‰)	Corrected Age
FR4B (cont.)	264	humates	3778	10,600±200	-19.2	10,690±200
	270	humates	3858	10,520±140	-19.8	10,600±140
	320	humates	90912	10,230±60	-17.4	10,350±60
	375	humates	3857	10,410±120	-17.5	10,530±120 h 3
	380	bone (Bison sp.)	3605	4,120±70	-10.5	4,350±70
	537	humates	3953	10,520±80	-18.2	10,630±80
FC1-T1	160	humates	4038	1,200±70	-18.7	1,300±70
FC2-T1	145	humates	4035	2,470±70	-18.2	2,580±70
	259	humates	4042	2,800±70	-16.2	2,950±70
FC3-T1	147	humates	4039	4,770±70	-14.9	4,940±70
FC3-T2	193	humates	4074	8,260±90	-16.7	8,400±90
FC4-T1	140	humates	4066	6,410±90	-15.2	6,570±90
FC5-T1	167	humates	4062	4,860±70	-13.6	5,040±70
	186	humates	4179	5,810±70	-15.0	5,970±70
FC5-T2	100	humates	4061	4,910±70	-14.9	5,080±70
	208	humates	4068	9,310±90	-17.1	9,430±90
	295	humates	4063	12,760±100	-21.0	12,830±100
FC6-T2	120	humates	4065	5,070±70	-14.1	5,250±70
	188	humates	4067	6,770±110	-15.8	6,920±110
	208	charcoal	4057	5,670±70	-25.8	5,660±70
	208	humates	4058	6,880±80	-19.2	6,970±80
	280	humates	4060	10,600±160	-18.0	10,710±160

Site Name (no.)	Depth (cm)	Material Assayed	ISGS Number	Uncorrected Age	∂13C (‰)	Corrected Age
PUMPHOUSE CR.						
PHC1-T4	161	humates	3997	1,080±70	-17.3	1,210±70
PHC1-T2	258	humates	4026	8,860±110	-15.8	9,010±110
PHC2-T2	305	humates	4177	2,800±70	-16.5	2,940±70
	376	charcoal & ash	3999	2,450±70	-21.2	2,510±70 h [3]
THREEMILE CR.						
TMC1-T1	307	humates	4059	9,000±90	-15.6	9,150±90
TMC1-T2	130	humates	4056	6,690±80	-17.2	6,820±80
SEVENMILE CR.						
FR13	91	humates	3852	4,540±70	-14.4	4,710±70
	146	humates	3651	6,820±80	-15.5	6,980±80
FR14	380	humates	3716	8,820±160	-19.7	8,910±160 h [3]
FR15	105	humates	3853	4,840±70	-14.7	5,010±70
	306	humates	3712	8,780±130	-17.6	8,900±130 h [3]
FR16	155	humates	3861	2,820±70	-16.3	2,960±70
1. samples not treated with 2N hot HCl						
2. Tx- (University of Texas Radiocarbon Laboratory)						
3. Age determined from hearth						

Alluvial units defined on the maps associated with the stream systems discussed below include collectively the flood plain or T0; terrace 1 or T1, which is lowest in elevation; terrace 2 or T2, which is next highest; terrace 3 or T3, which is higher yet; and fans.

Breakneck Creek. Except for the east branch, Breakneck Creek system exhibits very little flood plain (T0) due to apparent recent entrenchment (Fig. 3). Further, the period of entrenchment and subsequent lateral migration associated with Terrace 1 (T1) was likely of short duration because of the modest amount of surface area created prior to entrenchment to the present flood-plain level. During T1 time the channel did, however, cut into the north side of the distal portion of the upper alluvial fan (Fig. 4). Terrace 2 (T2) clearly dominates the system from the confluence down to where its valley opens onto the Kansas River valley (Fig. 5). Although no radiocarbon ages have yet been obtained from fill in this system, experience elsewhere on Fort Riley indicates that the T2 fill could be up to 10,000 years old, but based on soil development, a maximum estimated age of 5,000 years may be the case in this drainage.

Onemile Creek. In contrast to Breakneck, Onemile Creek exhibits appreciable T0 throughout the system. The prominence of flood plain in the upper reaches is typical of most small tributaries and develops because of the flashy, concentrated runoff that occurs in the upper watershed, i.e., these areas are characterized by active channels and frequent flushing of the valley fill. From the upper confluence to the lower valley limit, T1 is regularly distributed, occupying about one-third of the valley floor. The distal portion of the single large fan was apparently eroded during T1-lateral migration. T2 remnants have survived at scattered location along the main valley and into the north branch; most of these elements are at risk due to present channel migration. To facilitate an appreciation of the valley fill in the context of the entire landscape, Onemile Creek alluvial surfaces have been superimposed on the orthophotography (Fig. 6). The distribution of woodland defines the full drainage network of the system and its size relative to the Kansas River. The single alluvial fan is evident below a high-energy tributary, i.e., a drainage large enough to have sufficient runoff and sediment supply to build a fan, but not large enough to have the discharge to reach the channel in the main valley. Ages of the individual fill units are probably temporally related to those of the Breakneck Creek system.

Alluvial Fills of Breakneck Creek

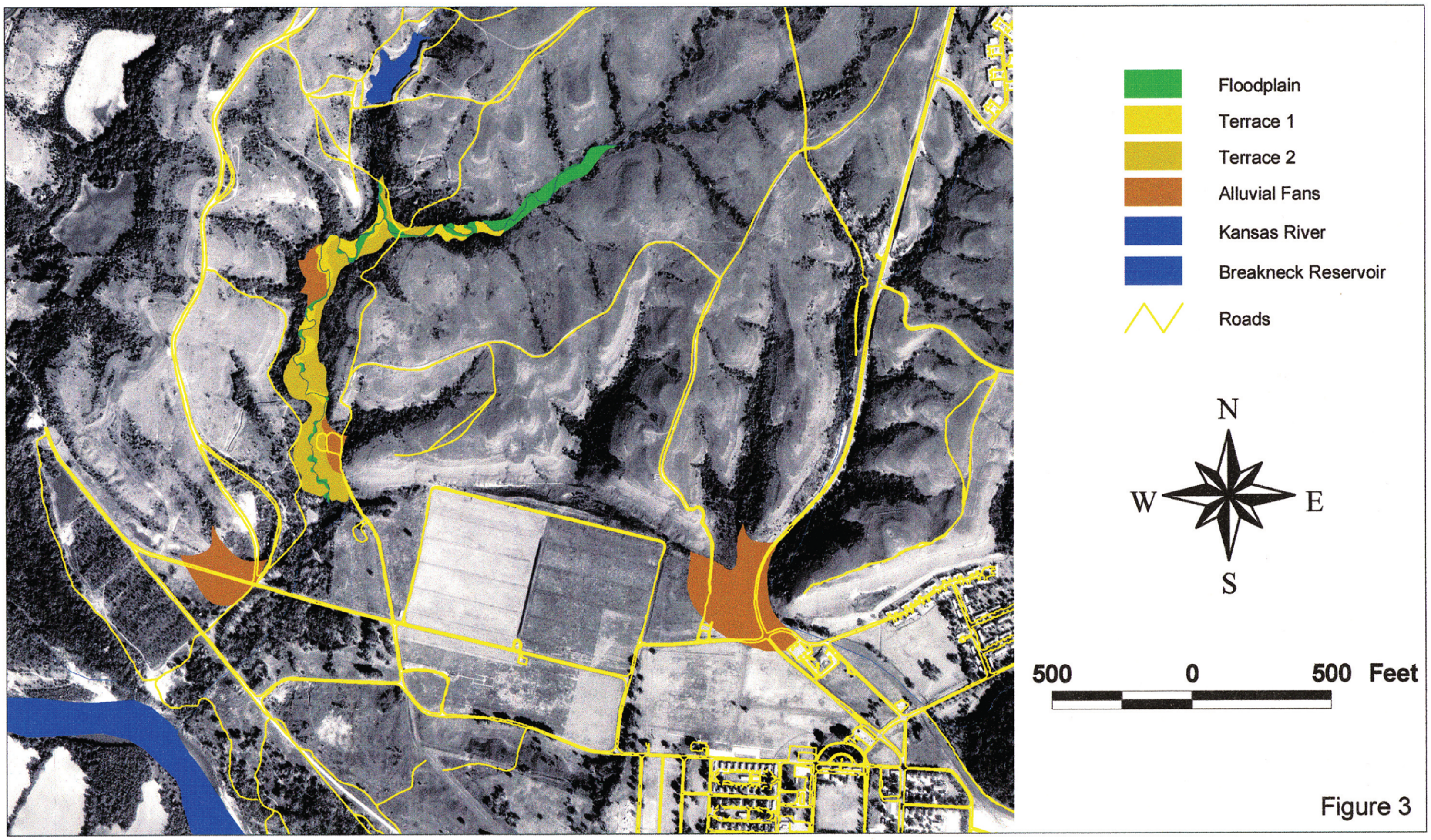


Figure 3

Upper Breakneck Creek

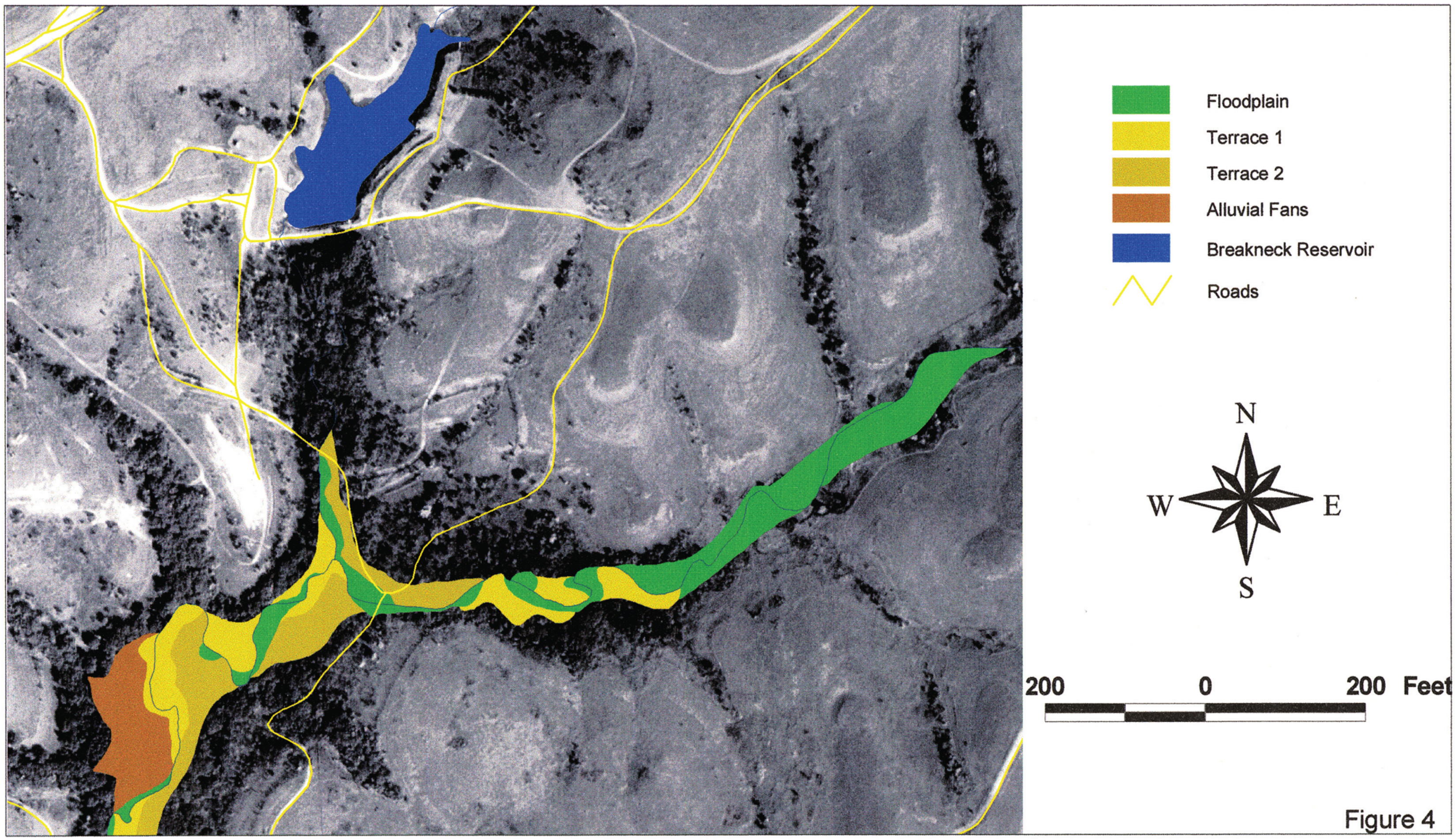


Figure 4

Lower Breakneck Creek

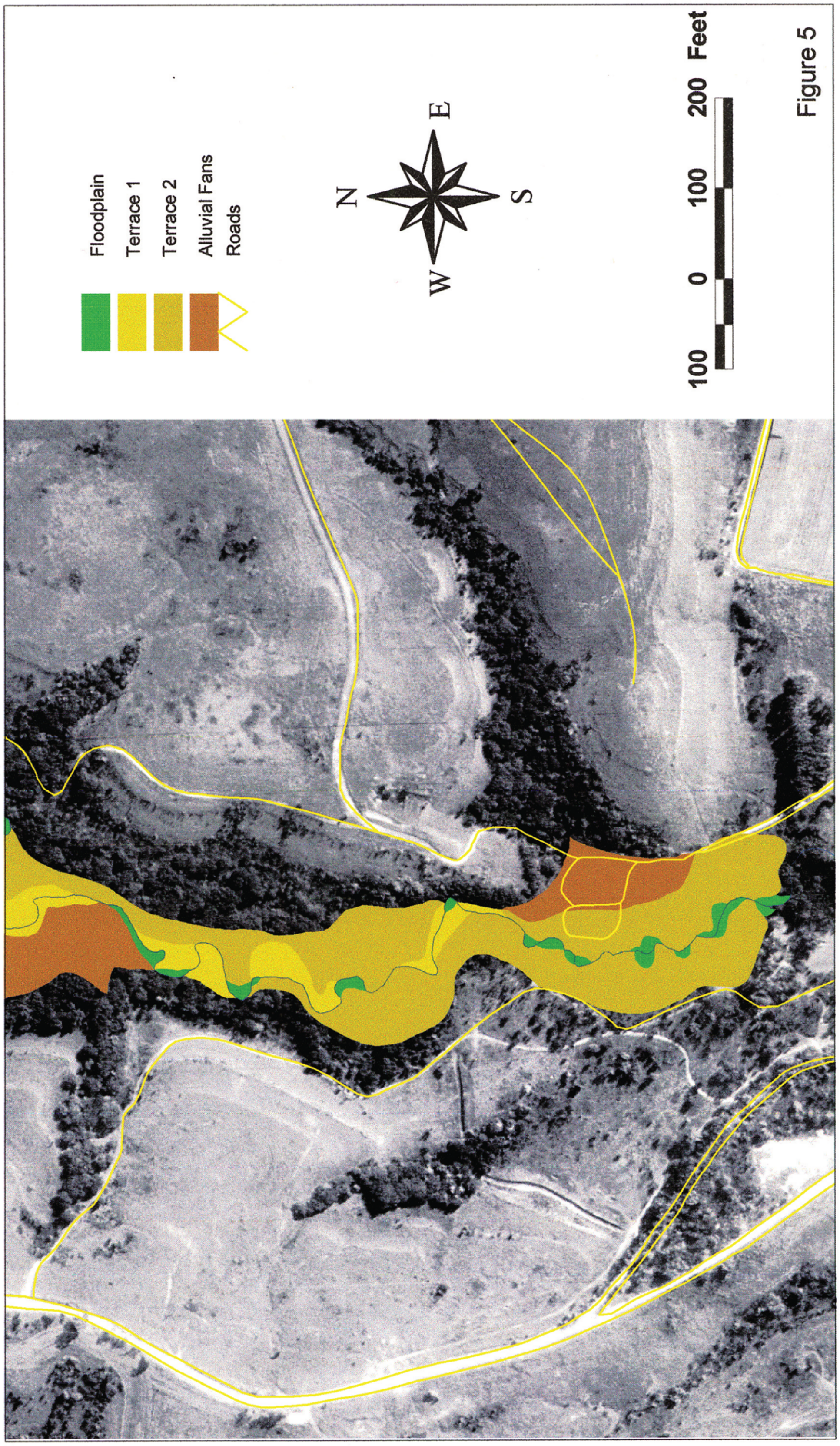


Figure 5

Alluvial Fills of Onemile Creek

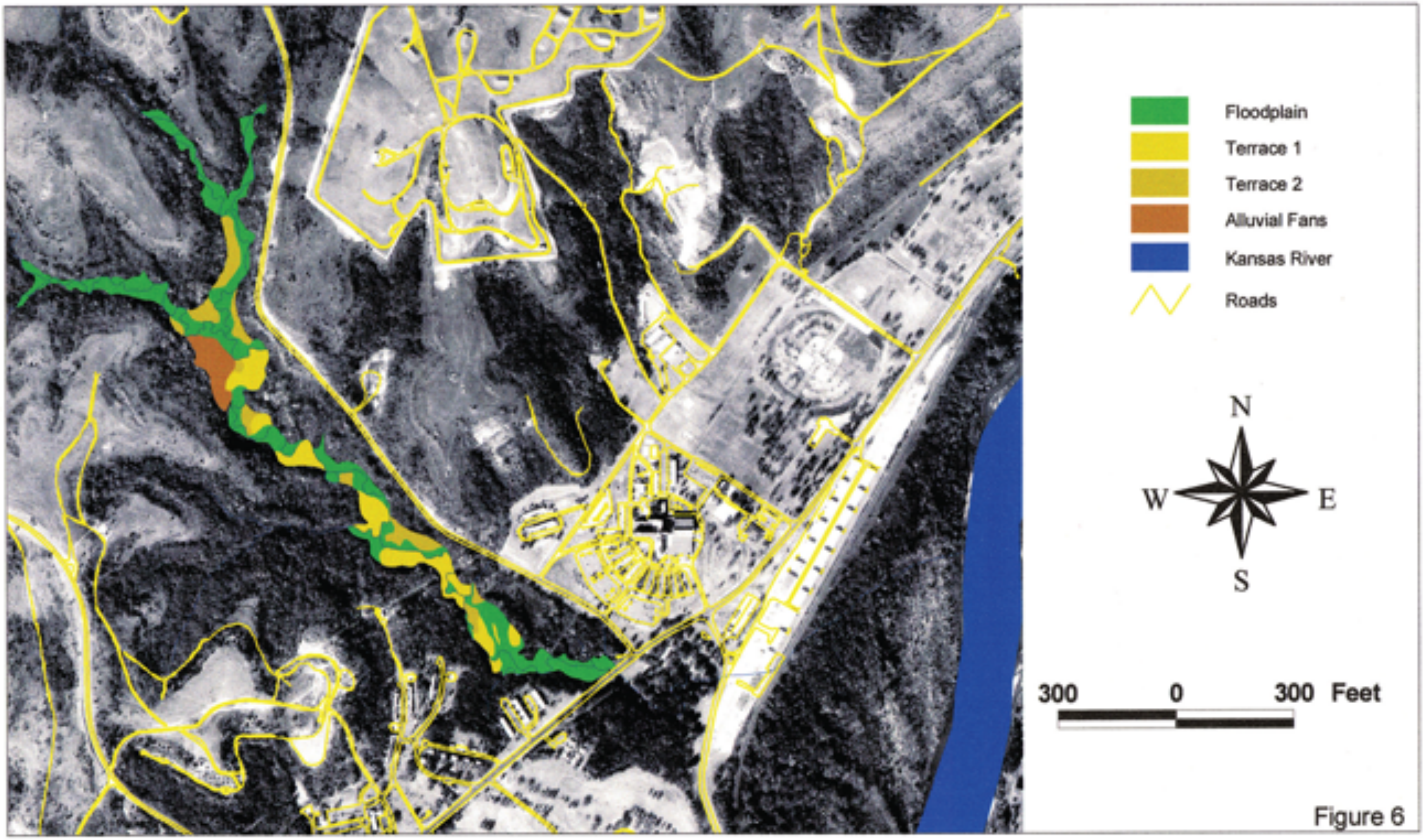


Figure 6

Pumphouse Creek. This system is characterized by a broad upper valley limited by Moon Lake, and narrow, bedrock-controlled, canyon-like lower valley, both of which are obvious in the width of alluvial fill mapped (Fig. 7). Flood-plain development is modest and uniform throughout the system, indicating an equilibrium longitudinal profile and a relatively short period of flood-plain development. Like the flood plain, the distributions of both terraces are fairly regular throughout the system, with T2 dominating the total valley bottom area. Four small alluvial fans, located above Moon Lake, have relatively steep surfaces and merge abruptly with the terraces and flood plain (Fig. 8). Despite the narrow nature of the lower bedrock valley, a large area of terrace has survived (Fig. 9). Overall, the alluvial surfaces of Pumphouse Creek are extremely well defined.

Three locations within the system were selected for radiocarbon dating: PHC2-T2 is a cutbank profile exposed in the T2 fill of lower Pumphouse Creek; it revealed three weakly developed buried soils, a hearth, and point bar deposit at the base. Two ages obtained from the site are similar (Table 1): charcoal and ash for the hearth dated to about 2,500 yr B.P., whereas the buried soil in which it was located dated to about 2,900 yr B.P. The disparity is probably due to the latter date being contaminated by redeposition of older carbon in the sediments within which the soil formed. PHC1-T2, also located in T2 fill provided a much older age of about 9,000 yr B.P.; the age is most likely accurate and representative of the fill age. Inspection of the T2 fill in the system indicates that it consisted of two episodes of cutting and filling, the latter of which cut into the 9,000-yr old fill and replaced part of it up to the same level. Most of the T2 fill in the main valley appears, however, to date to 9,000 yr B.P. The site in T1 fill, PHC1-T4, provided an age younger than either T2 fills, which indicates that T1 fill ranges from about 1,500 to 1,000 years in age.

Forsyth Creek. Five different alluvial surfaces appear in the Forsyth drainage, and, with one exception, these are regularly distributed along the main valley (Fig. 10). T0 is developed to a small extent throughout, but T1 and T2 clearly dominate, with four distinct, large areas of coalescing fans. The largest area of T0 is located at the confluence of the two branches forming the main valley, a network position where such channel mobility is anticipated (Fig. 11). The Williston Point area, another valley confluence, still retains large terrace remnants, in particular the triangular-shaped unit ofT2 wedged between the main channel and the tributary (Fig. 12). The largest terrace remnants are found in lower Forsyth, at its confluence with Threemile Creek (Fig. 13), where all five alluvial units appear.

Ten sites, all from backhoe trenching, were investigated in the Forsyth Creek valley. FR 4B, a T2 site at the confluence, produced radiocarbon age ranges about 11,000 to 8,000 yr B.P., whereas FC6-T2, a site in that same area, produced ages from about 11,000 to 5,200 yr B.P. (Table 1). The existence of an older uppermost age at the former site may be due to the stripping (≤1m) taking place during development of the power line corridor, i.e., the younger buried soil was mechanically removed. Four T2 sites in the Williston Point area indicated fill ages that range from about 5,000 to 12,000 yr B.P., as does T2 site FC4-T1 upstream. T2 fill ranges in age from over 12,000 to about 5,000 yr B.P. T1 fill was dated at three sites, FR4A, FC1-T1, and FC2-T1, all of which indicate ages less

Alluvial Fills of Pumphouse Creek

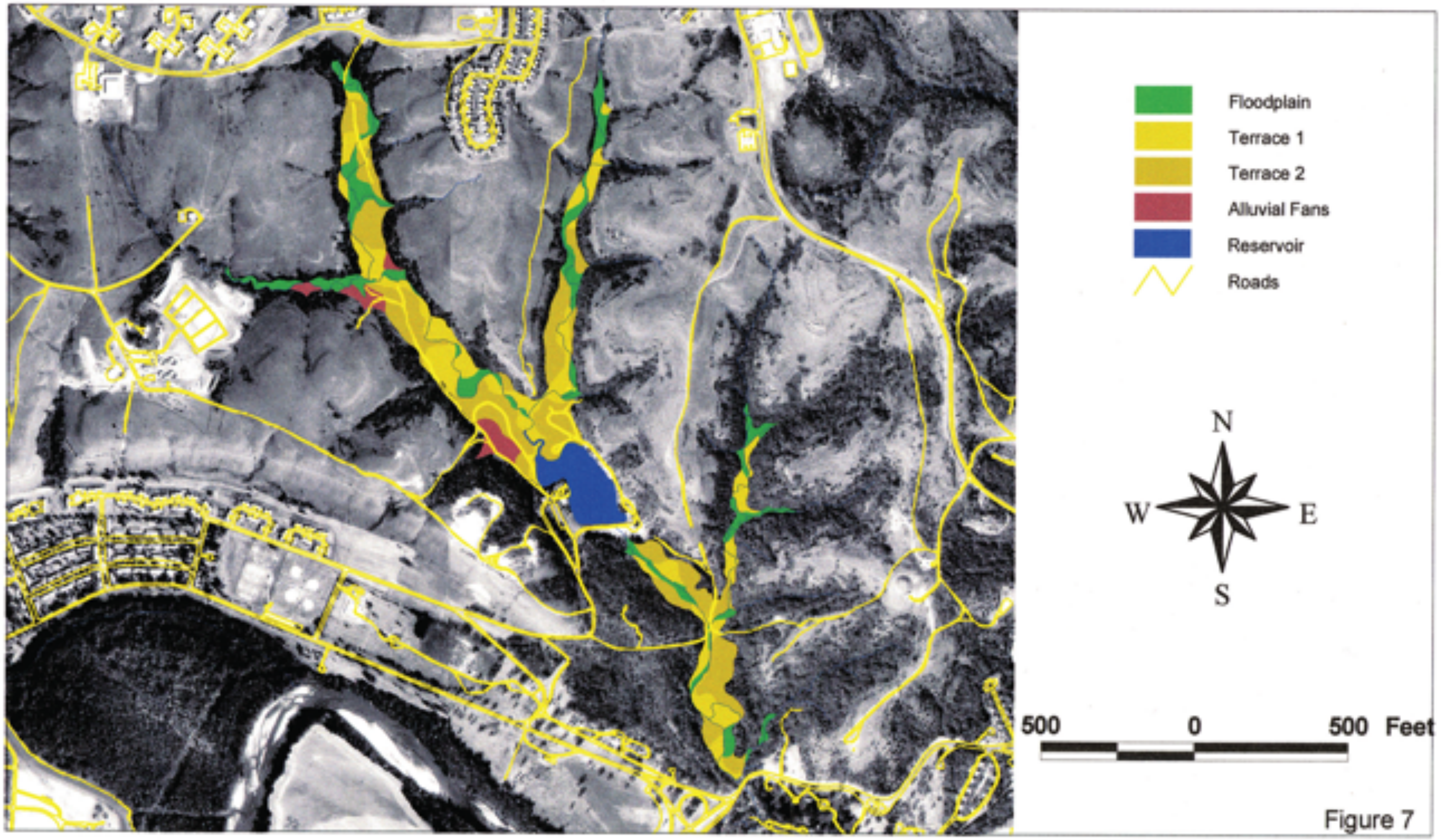


Figure 7

Middle and Upper Pumphouse Creek

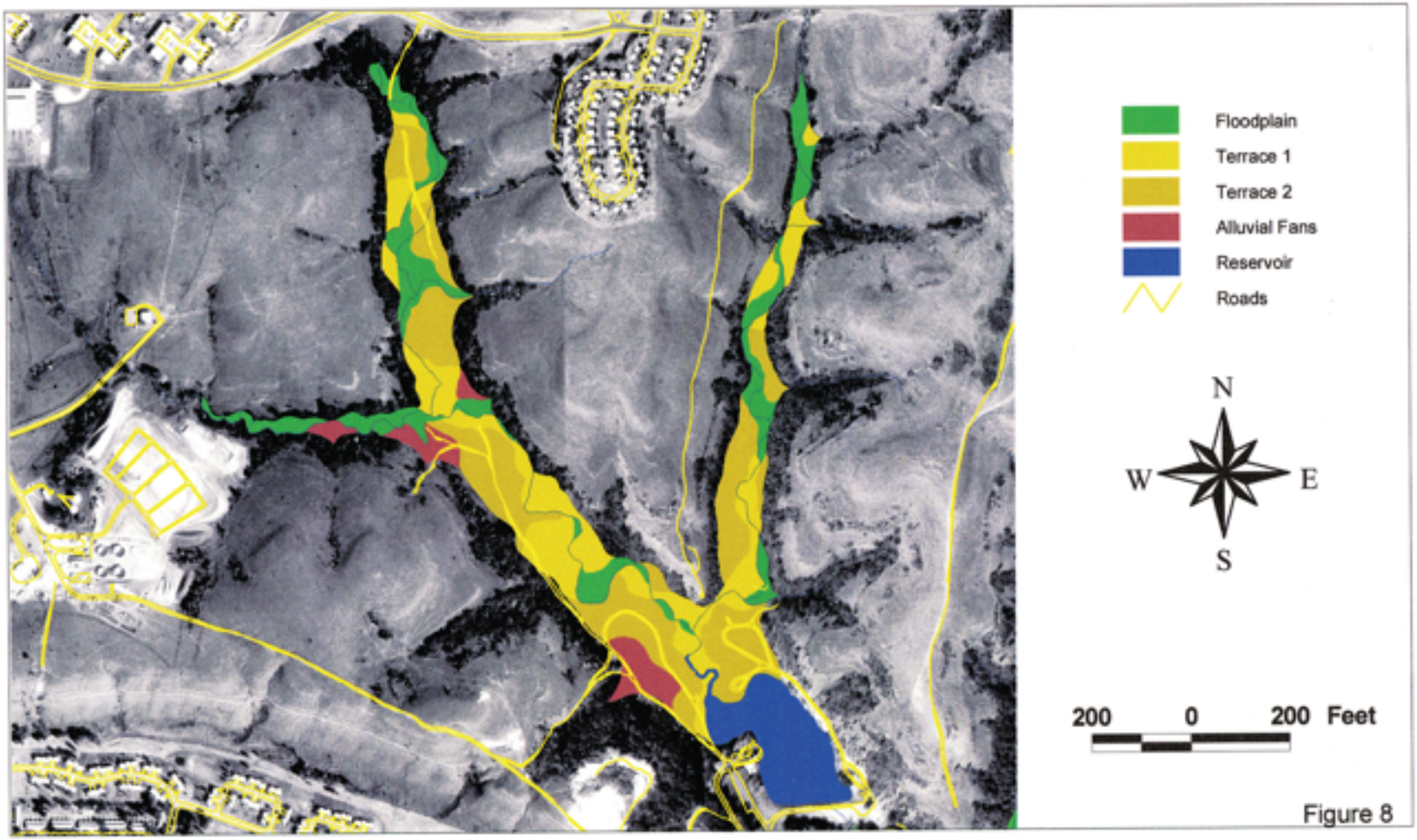


Figure 8

Lower Pumphouse Creek

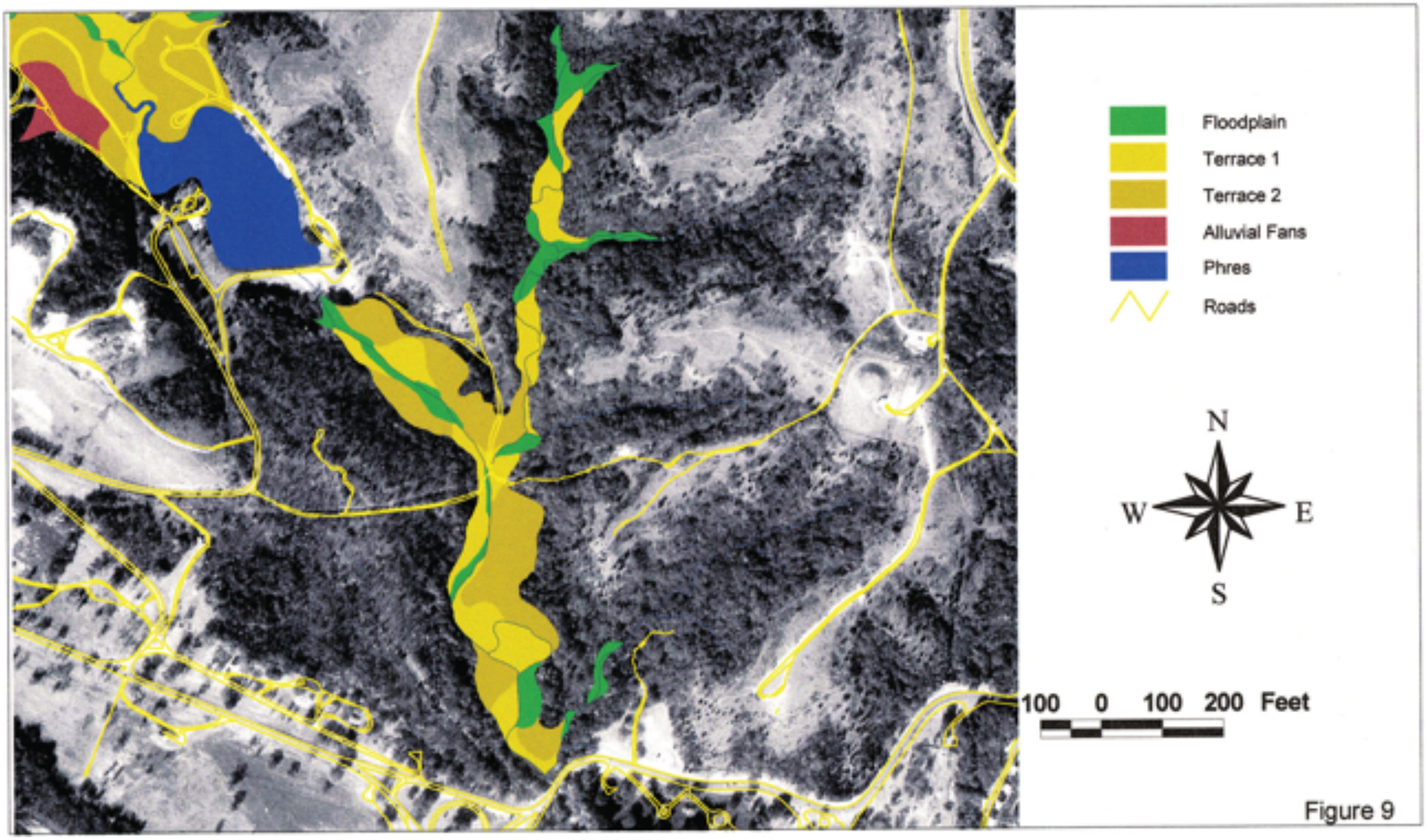


Figure 9

Alluvial Fills of Forsyth Creek

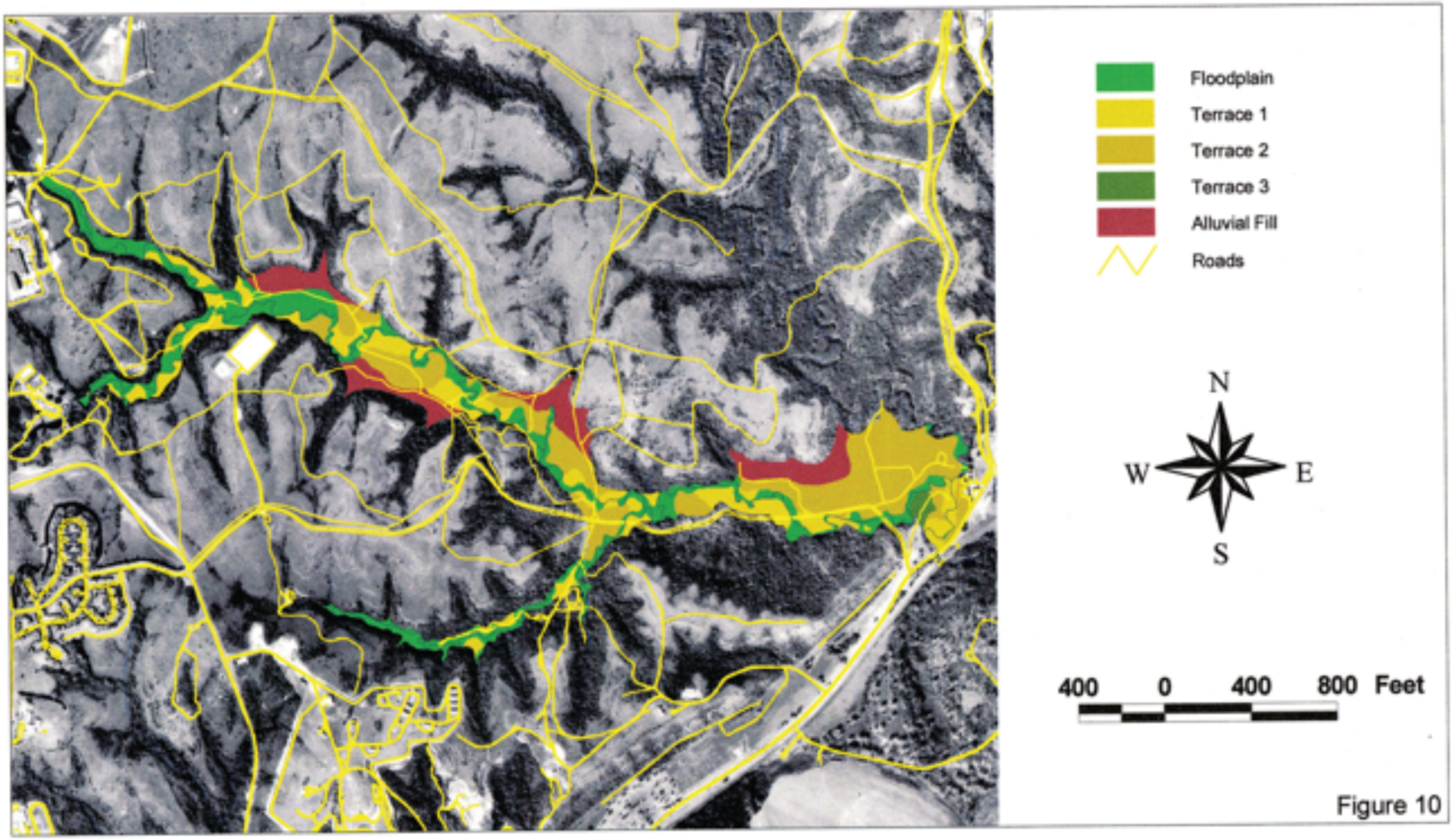


Figure 10

Upper Forsyth Creek

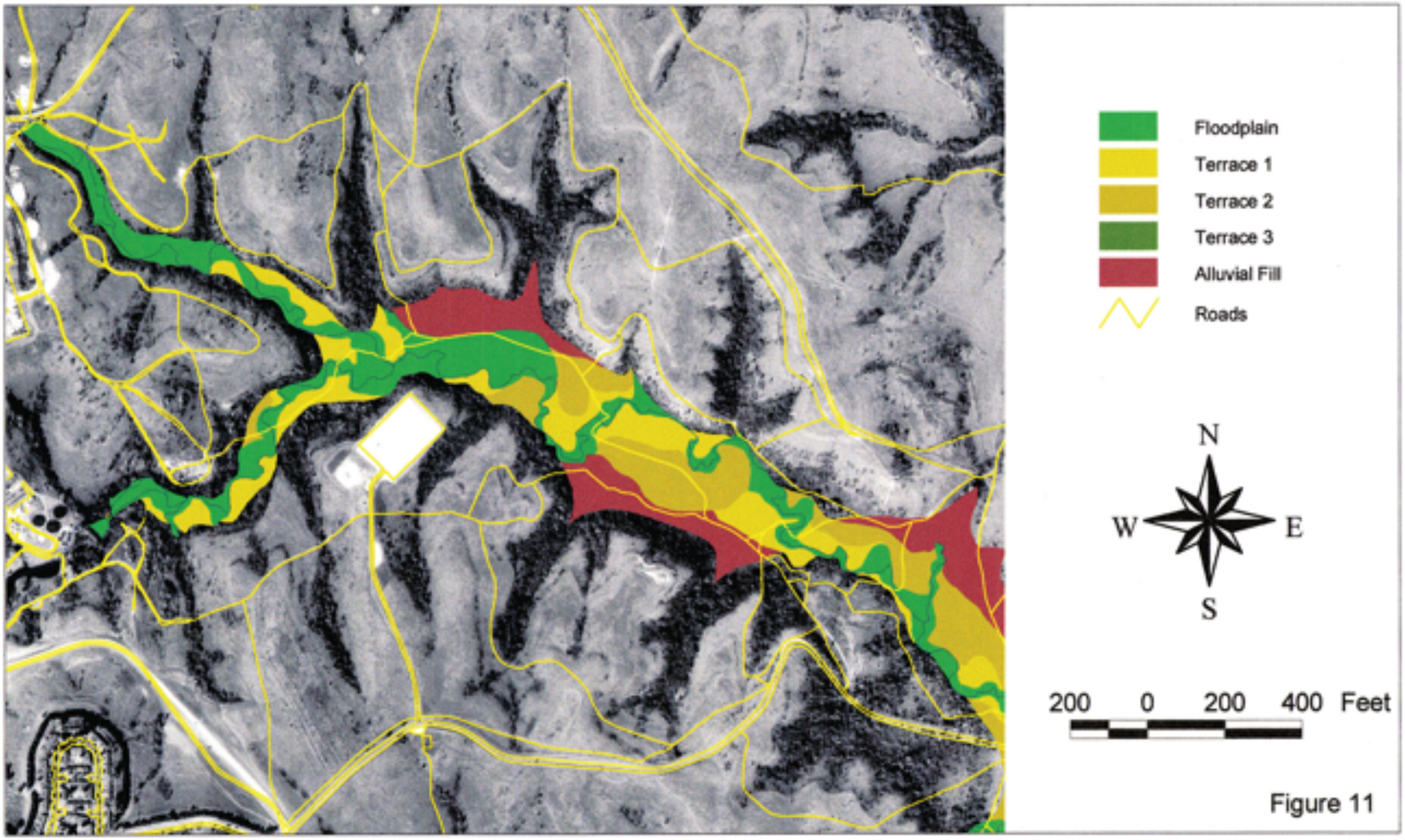


Figure 11

Williston Point - Forsyth Creek

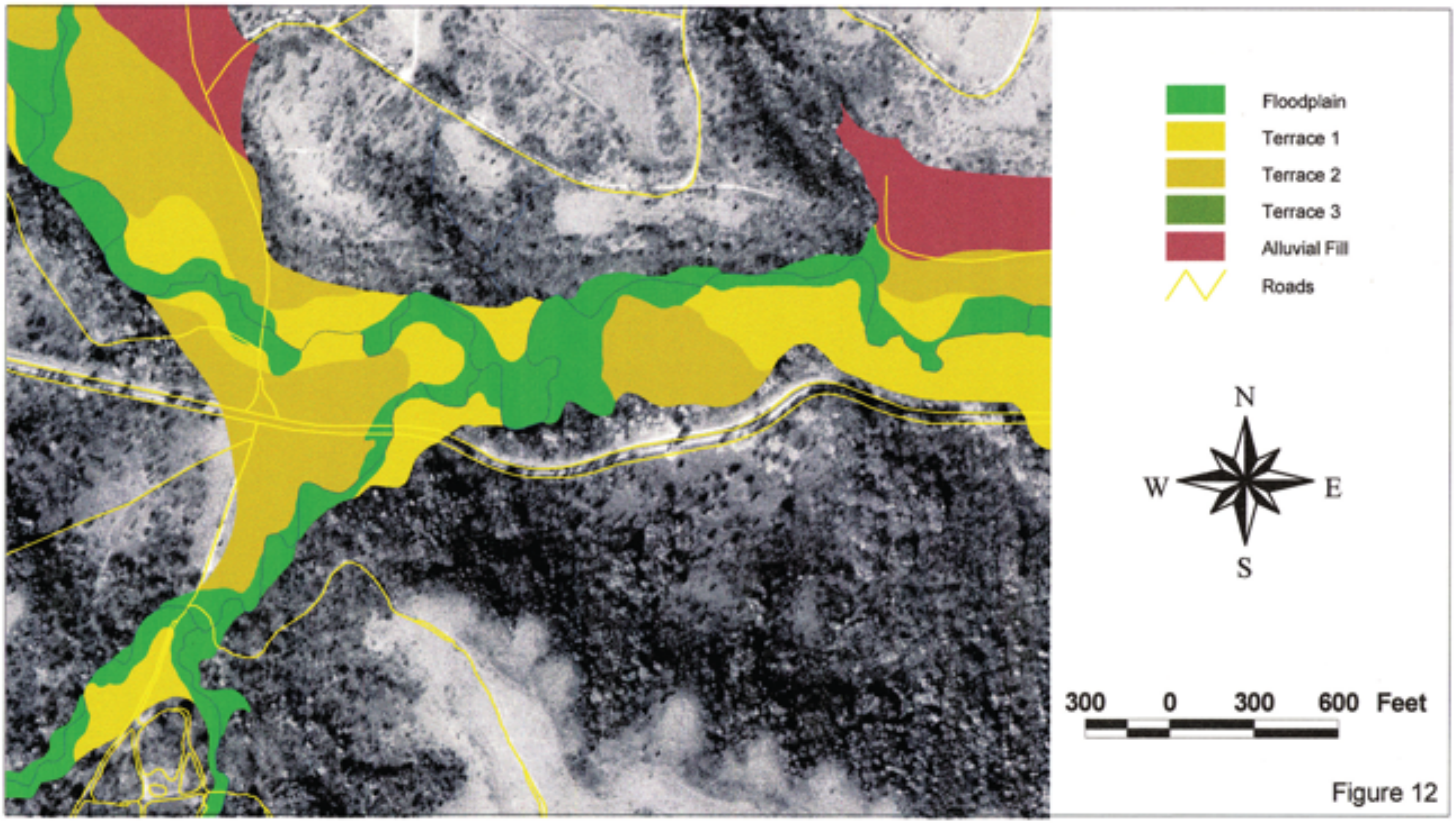


Figure 12

Confluence of Forsyth and Threemile Creeks

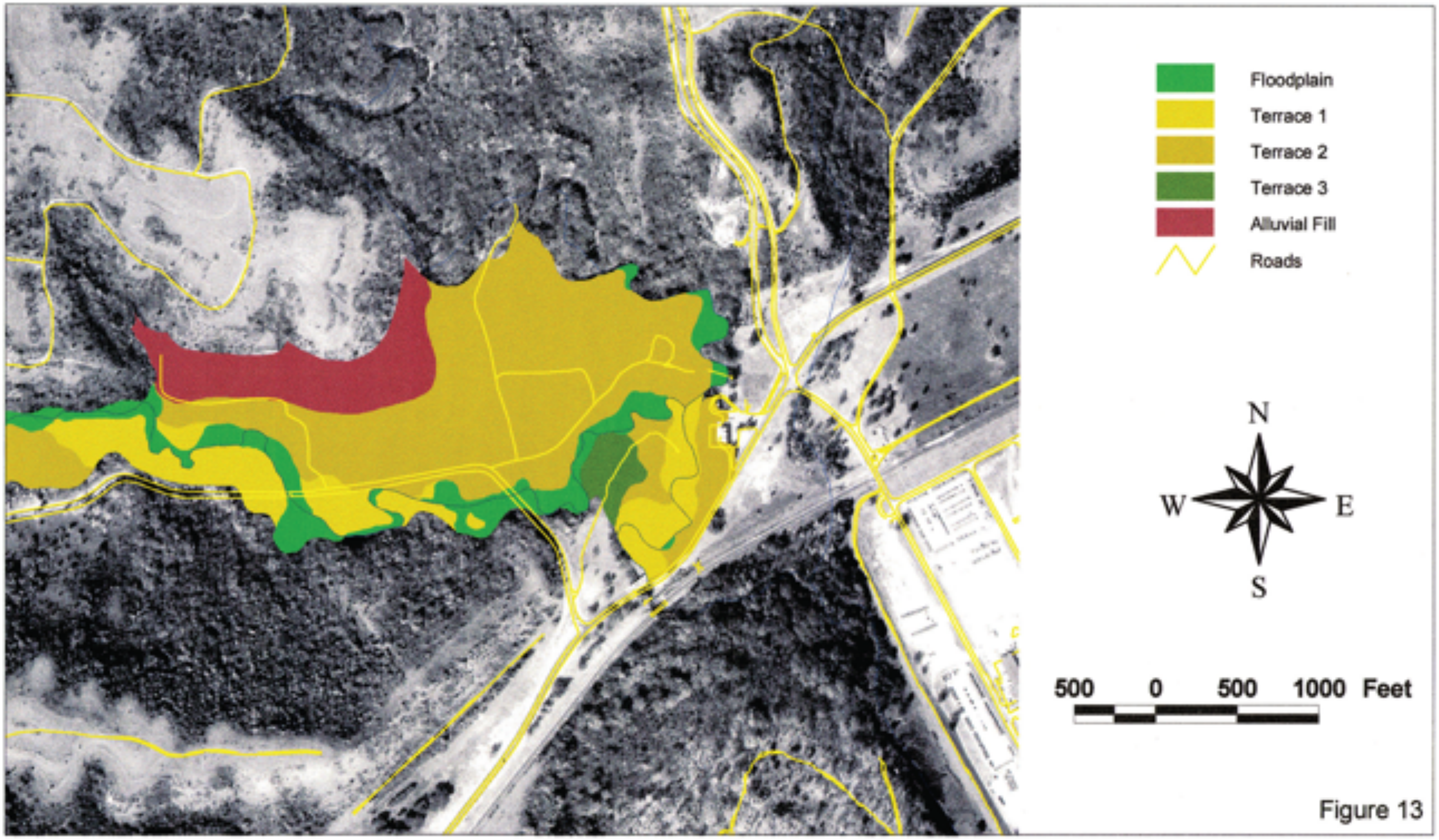


Figure 13

than 5,000 to about 1,000 yr B.P. The older age of 6,740 yr B.P. from FR4A probably reflects contamination from older carbon since this was not a soil that was dated, but rather a silt drape from a flood, which would have transported older, recycled organic (plant-derived) and inorganic (rock-derived) carbon.

Wildcat Creek. The strange, incomplete appearance of the pattern of alluvial fills in Wildcat Creek is a function of adherence to the base boundary extending down the valley axis (Fig. 14). Even with this incomplete mapping, the dominance of the T2 in the main valley is obvious: T0 and T2 are poorly developed throughout the mapped reach (and beyond). The pattern of T1 fill indicates that a limited amount of lateral migration occurred then, prior to entrenchment to the present level. The recent nature of the entrenchment is apparent: although the channel is highly meandering and characterized by actively eroding cutbanks, little of the T1 and adjacent T2 has been removed. Coalescing fans are common, especially in the upper reaches of the main valley (Fig. 15). In fact, fans dominate the Little Arkansas Creek; due to the coarse and active nature of the fans, the channel has, in one area, occupied a straight course for a long time, i.e., no terrace fill has been deposited (Fig. 16). The valley bottom in the lowermost part of the valley appear as a series of stair steps: T0, T1, T2, and fan deposits are all in close proximity to one another and have distinct scarps at their contacts (Fig. 17).

Radiocarbon ages from three different fills provide the greatest temporal range of the study stream systems. Sites WC1 and WC5-T2 are located on alluvial fans, and yielded basal ages in excess of 24,000 yr B.P., yet the uppermost age at WC1 was only about 1,900 yr B.P. Ages from the sites of T2 fill (WC4-T2, WC5-T6) indicate an age range from over 10,000 yr B.P. to as young as 3,000 yr B.P. Accordingly, T1 sites (WC4-T1, WC4-T3, and WC5-T1) ranged from less than 3,000 yr B.P. to about 1,000 yr B.P.

Predictive modeling of buried cultural remains.

Because the Fort Riley project is geoarchaeologically focused, the ultimate question posed by this investigation concerns the preservation of cultural materials, particularly in a buried context. Investigations of cultural material located at or near the land surface on Fort Riley have demonstrated that aboriginal peoples made use of the entire landscape, the evidence of which is preserved primarily in a buried context.

Since the archaeological record is concentrated in the last 12,000 years (Table 2), our investigations have centered on deposits of that antiquity. On the uplands, this time period is represented by the Brady soil, developed in terminal Peoria loess, and by overlying Bignell loess, deposited periodically during approximately the last 9,000 years. Consequently, the distribution of such lithostratigraphic and pedostratigraphic units on the uplands dictates where the potential for buried cultural material exists. Aboriginal activity was concentrated in valleys of the central Great Plains because of the relatively rich resource base, and Fort Riley is a prime place to observe this concentration. Alluvial fills range in age from pre-12,000 BP to the present, and most fills contain soils, evidence of stable flood-plain environments.

Alluvial Fills of Wildcat Creek

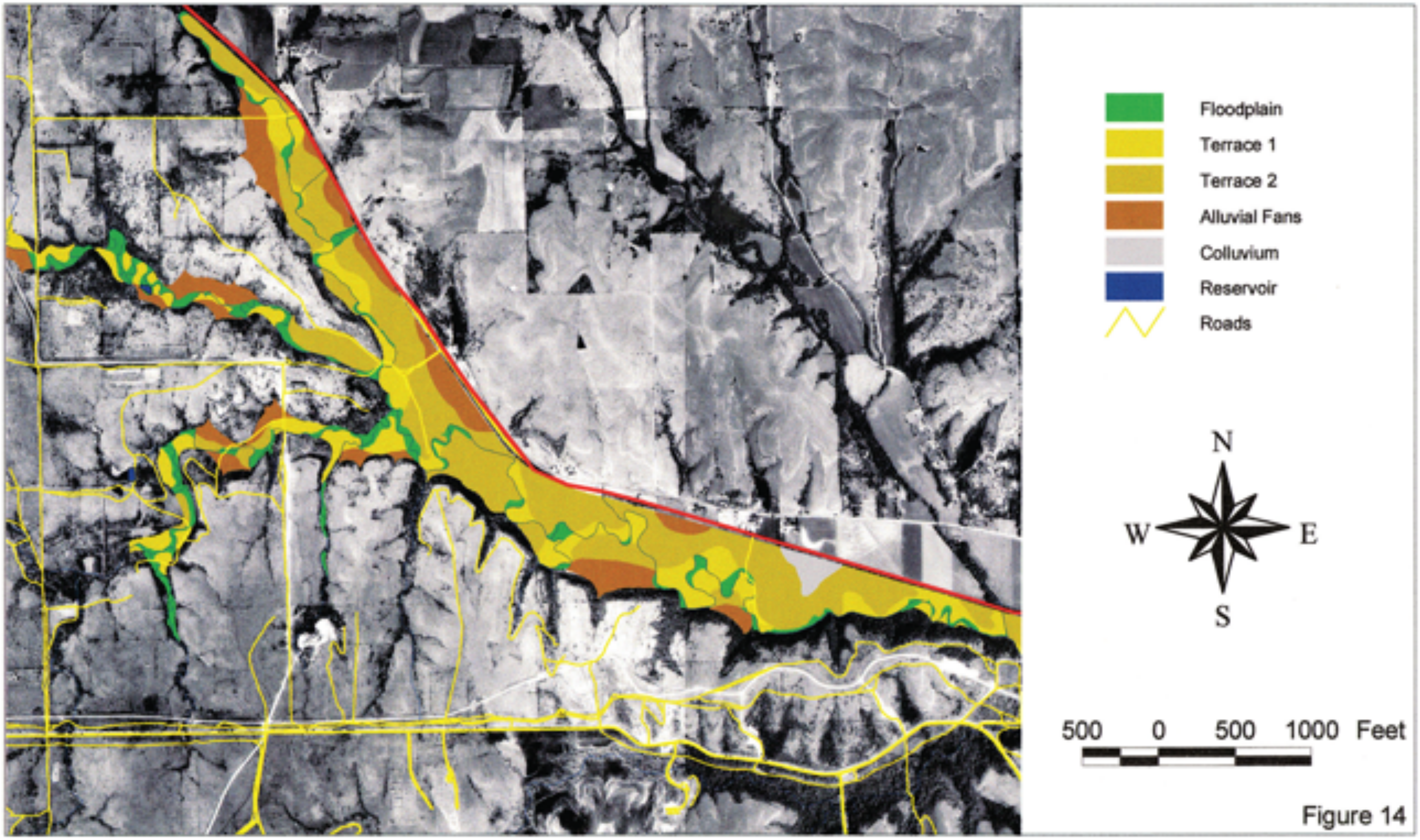


Figure 14

Upper Wildcat Creek

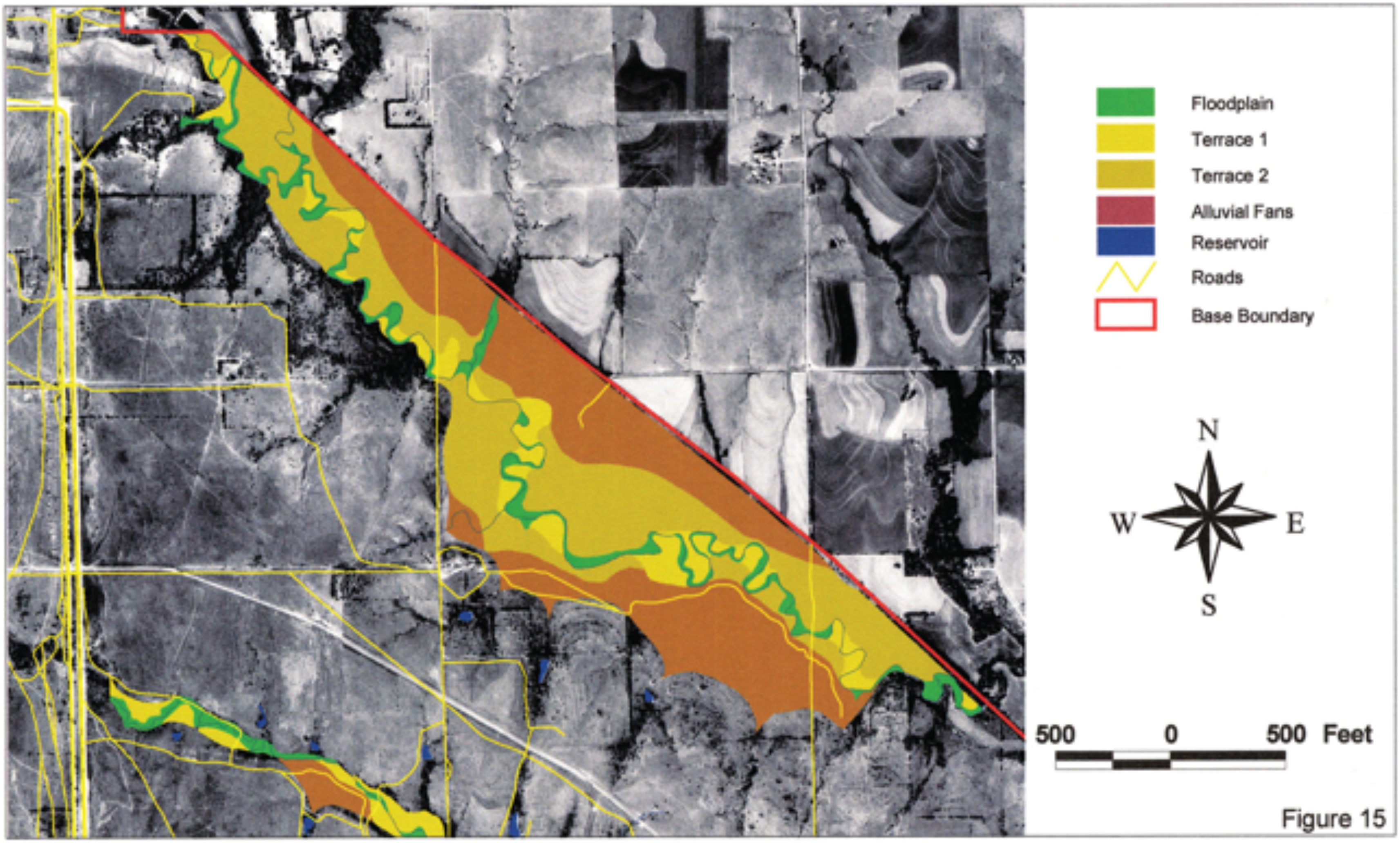


Figure 15

Little Arkansas Creek - Wildcat Creek

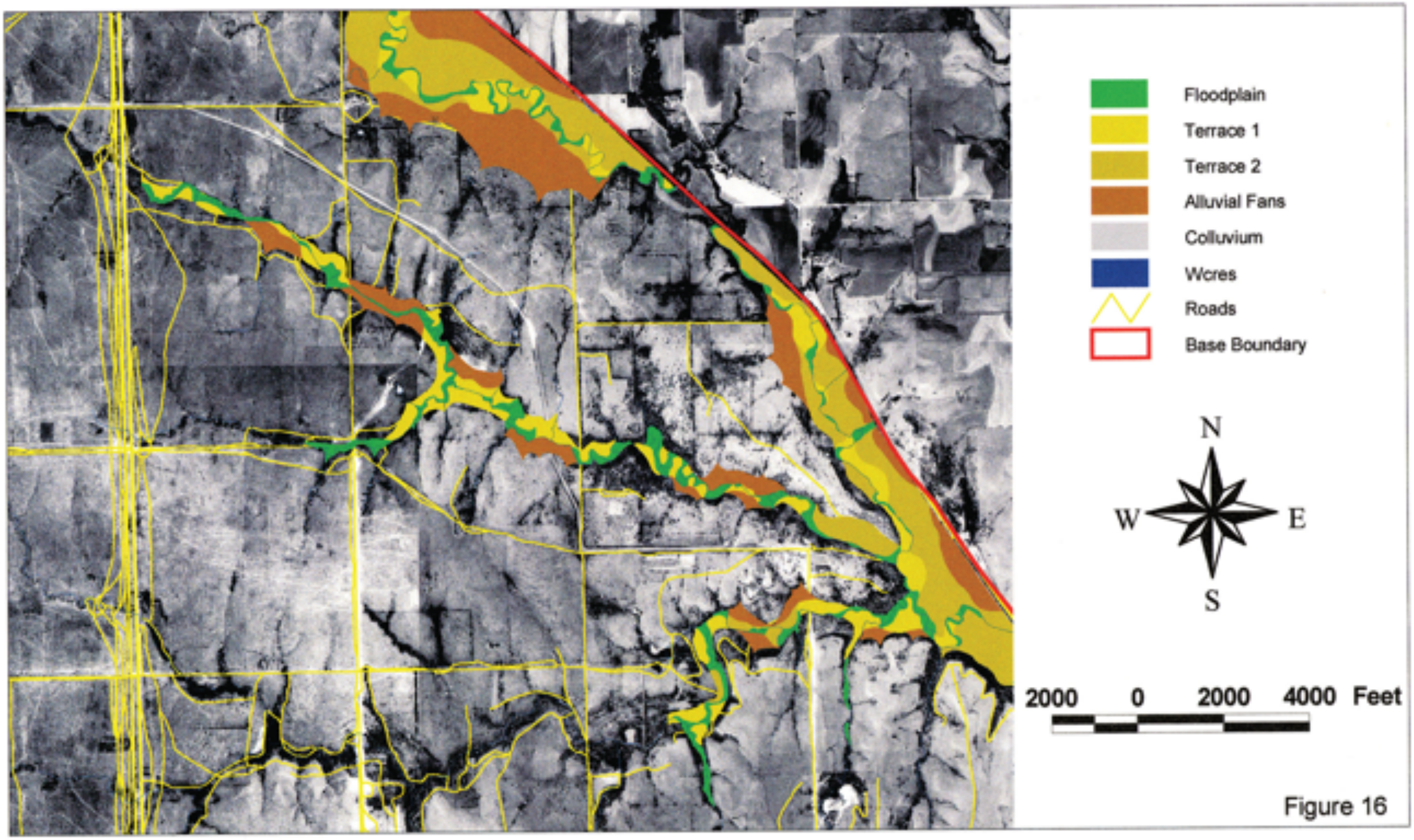


Figure 16

Lower Wildcat Creek

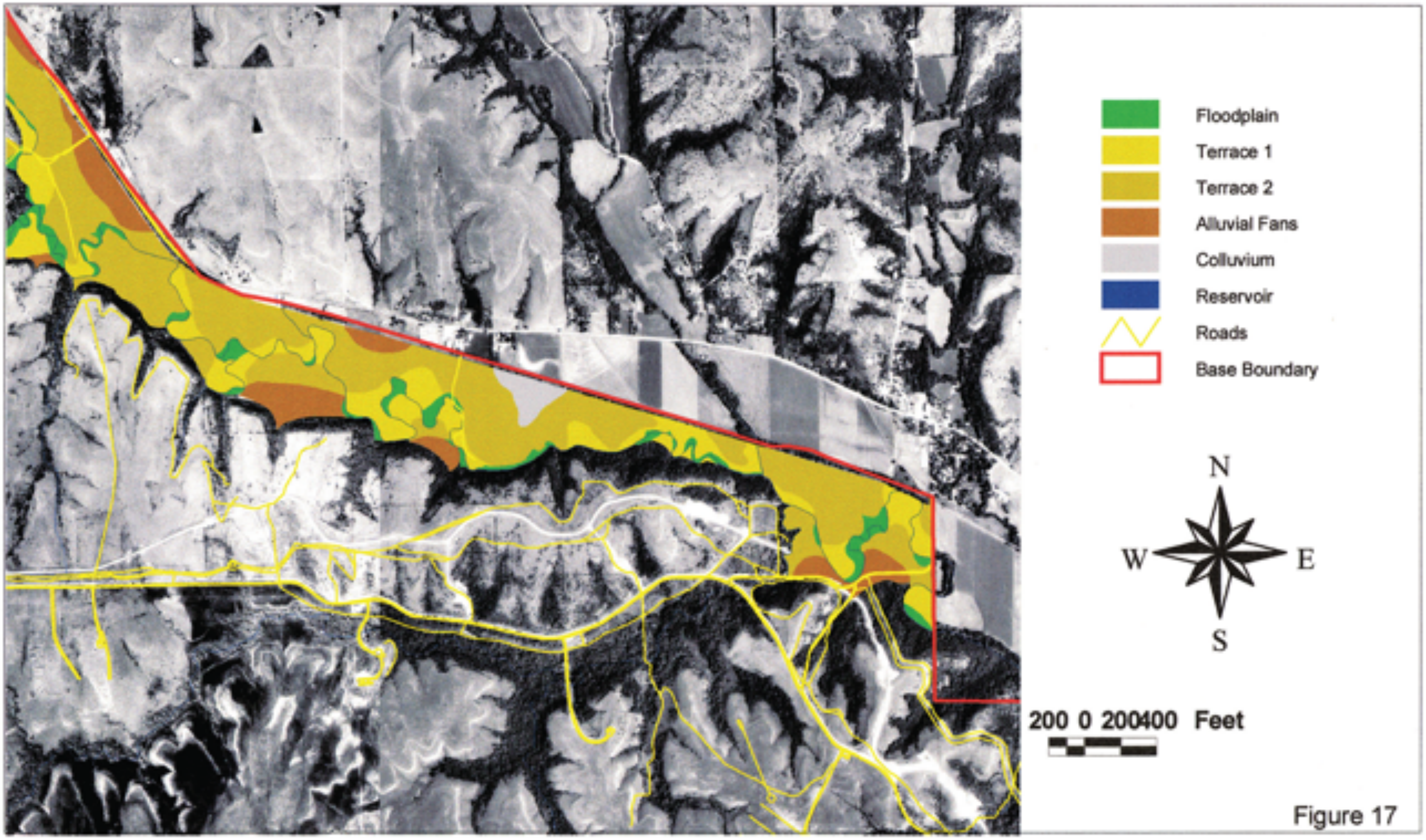


Figure 17

Table 2. Central Great Plains Cultural Chronology

Paleoindian	12,000 - 9000 BP 10,050 - 7050 BC
Early-Middle Archaic	9000 - 5000 BP 7050 - 3050 BC
Late Archaic	5,000 - 2,000 BP 3050 - 50 BC
Early-Middle Woodland	2,000 - 1,500 BP 50 BC - AD 450
Late Woodland, Late Prehistoric, and Protohistoric	1,500 - 250 BP AD 250 - 1700

Through a process of separating the various individual alluvial surfaces from one another, the areas with certain fill age attributes can be appreciated in the context of the potential for burial of remains from particular cultures. This has been done for three systems representing different drainage sizes: Pumphouse, Forsyth, and Wildcat creeks. A synthesis of ages of fill and cultural associations indicates similarities among the small (Pumphouse), medium (Forsyth) and large (Wildcat) valleys (Table 3). Youngest cultural material (Late Prehistoric to Protohistoric and Historic) is associated with the flood-plain deposits. Because these deposits are being rework so extensively, it is unlikely that any archaeological material will be in situ, however; conversely, cultural material predating the age of the flood plain may be redeposited in the fill, e.g., a bark beater (Late Woodland?) was found in with the gravel lag on a channel point bar in Wildcat Creek. T1 fill in Forsyth and Wildcat creeks is Late Archaic to Late Woodland in age, whereas the T1 fill of Pumphouse Creek appears to have been deposited in a very brief interval, about 500 years. T2 fill clearly dates from the Paleoindian era into the Archaic, with Pumphouse Creek again being a bit different from the other two systems. Only Forsyth Creek has any T3 recognized, and the aerial extent is extremely limited. Because the T2 is inset, the T3 is of presumed pre-Paleoindian age, and any associated archaeological materials would be located within the upper few tens of centimeters. Alluvial fans merit special attention because of their aerial extent in some systems and extreme range in age of their fill, i.e., pre-Paleoindian to Early Woodland, where dated in Wildcat valley.

Table 3. Buried Cultural Associations and Estimated[1] Threshold Ages[2] for Alluvial Fills

Fill	Pumphouse Creek	Forsyth Creek	Wildcat Creek
T0	Late Prehistoric-Protohistoric (≤1,000)	Late Prehistoric-Protohistoric (≤1,000)	Late Prehistoric-Protohistoric (≤1,000)
T1	Late Woodland (1,500-1,000)	Late Archaic-Late Woodland (5,000-1,000)	Late Archaic-Late Woodland (3,000-1,000)
T2	Paleoindian-Late Woodland (>9,000-1,500)	Paleoindian-Middle Archaic (13,000-5,000)	Paleoindian-Late Archaic 11,000-3,000)
T3		None (all surficial) (>13,000)	
Fans	Paleoindian-Early Woodland(?)	Paleoindian-Early Woodland(?)	Paleoindian-Early Woodland(24,000-1,800)
1. from ^{14}C ages and presumed sedimentation rates 2. years B.P.			

Pumphouse Creek. Individual depictions of T0, T1, T2, and fan extent (Figs. 18-21) suggest that the majority of the valley fill has the potential to contain buried sites. Late Woodland-age fills are extensive (T1), but the older Paleoindian and Archaic-age fills are most extensive. Cutbank exposures of cultural features, including the hearth dated to the Late Archaic, attest to the presence of buried cultural materials in these fills.

Forsyth Creek. The relative area of flood plain is greater in Forsyth than Pumphouse, but it is still a small part of the total valley fill (Fig. 22). A sizable area is involved in the T1 and T2 fill distributions, particularly the latter (Figs. 23, 24). The large area of T2 fill at the confluence with Threemile Creek, dating to Paleoindian and Archaic, very likely contains buried cultural material and sites due to its resource-rich location. A similar confluence area in lower Sevenmile Creek, containing a large expanse of T2 fill, produced Early Archaic hearths in three of four backhoe trenches (Table 2). T3 fill should have only surficial cultural material, and that small remnant has been heavily modified by road construction (Fig. 25). Although undated in Forsyth Creek, the alluvial fan fill appears, from color and stratigraphic position, to be ages similar to those in Wildcat Creek where temporal determinations have been made, i.e., pre-Paleoindian to Woodland (Fig. 26).

Late Prehistoric to Protohistoric Sediments

Pumphouse Creek

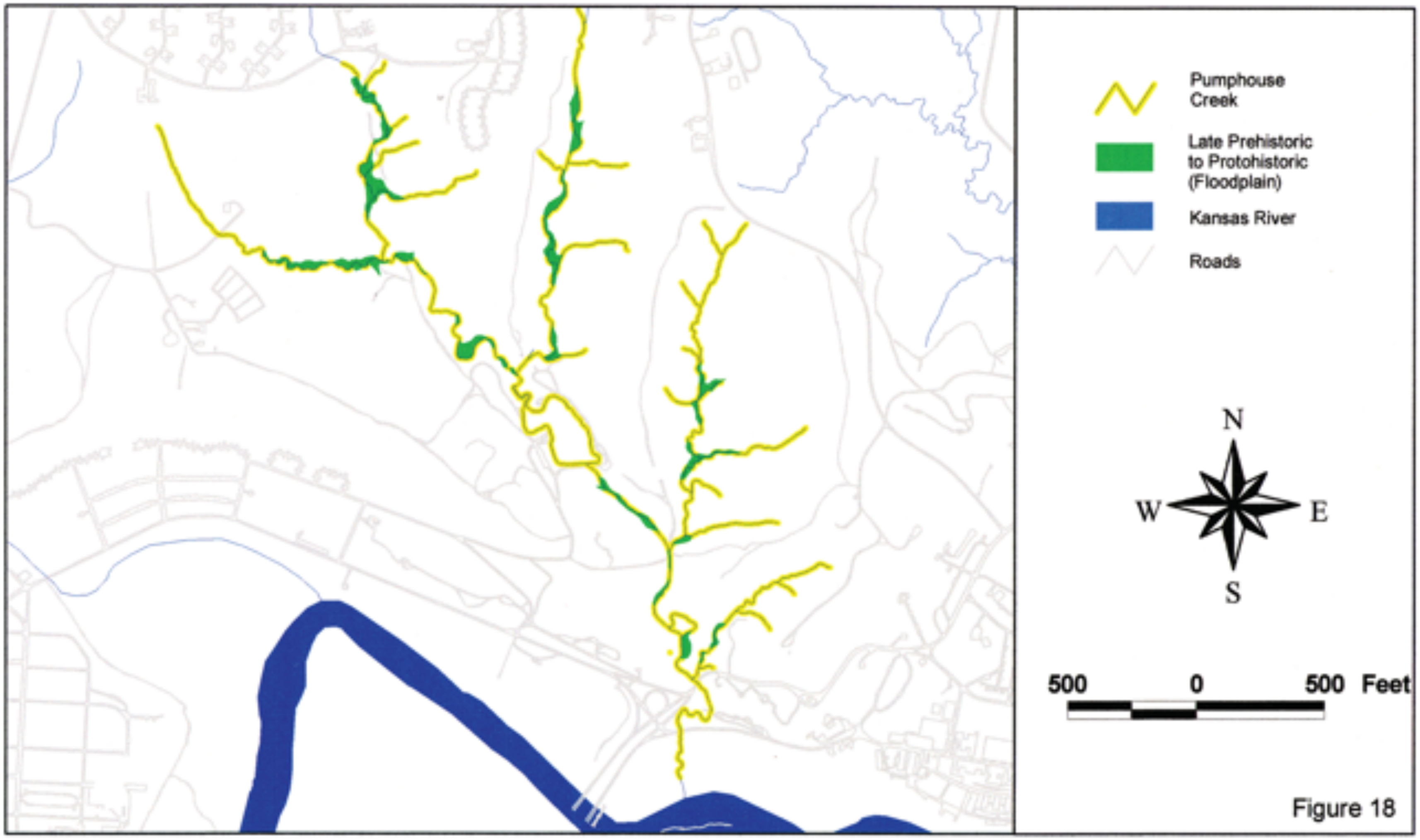


Figure 18

Late Woodland Sediments

Pumphouse Creek

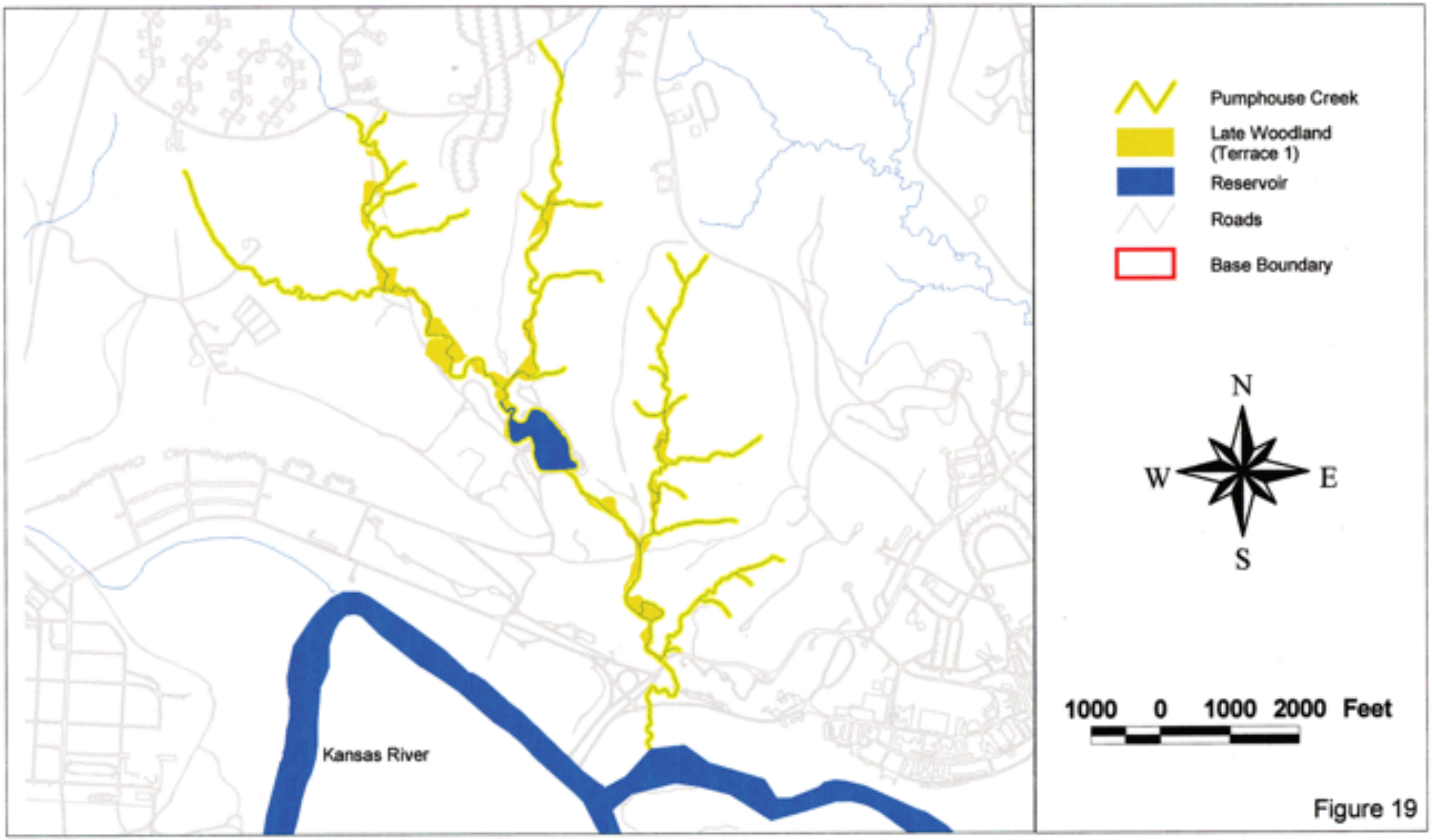


Figure 19

Paleoindian to Late Woodland Sediments

Pumphouse Creek

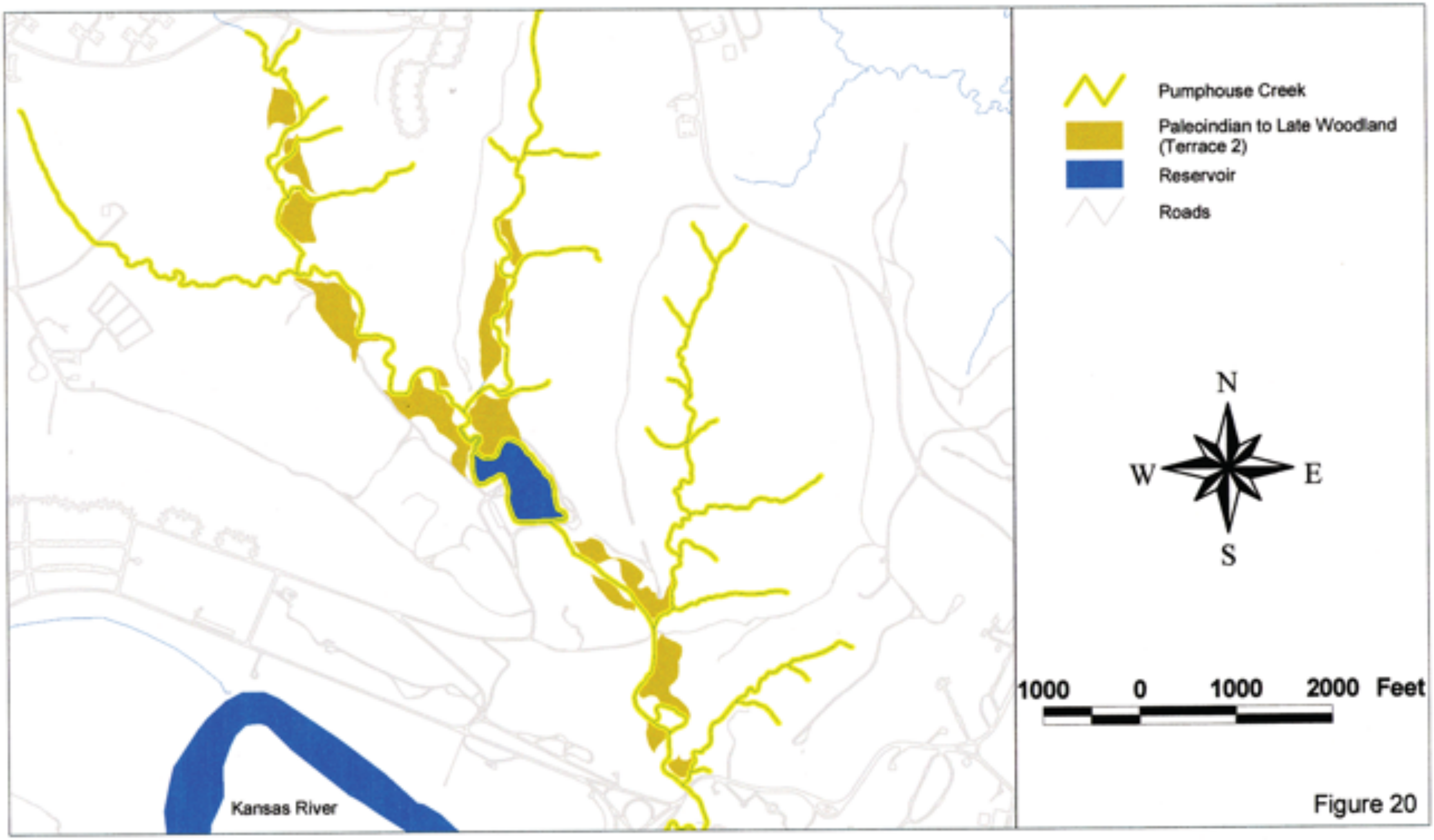


Figure 20

Paleoindian to Early Woodland Sediments

Pumphouse Creek

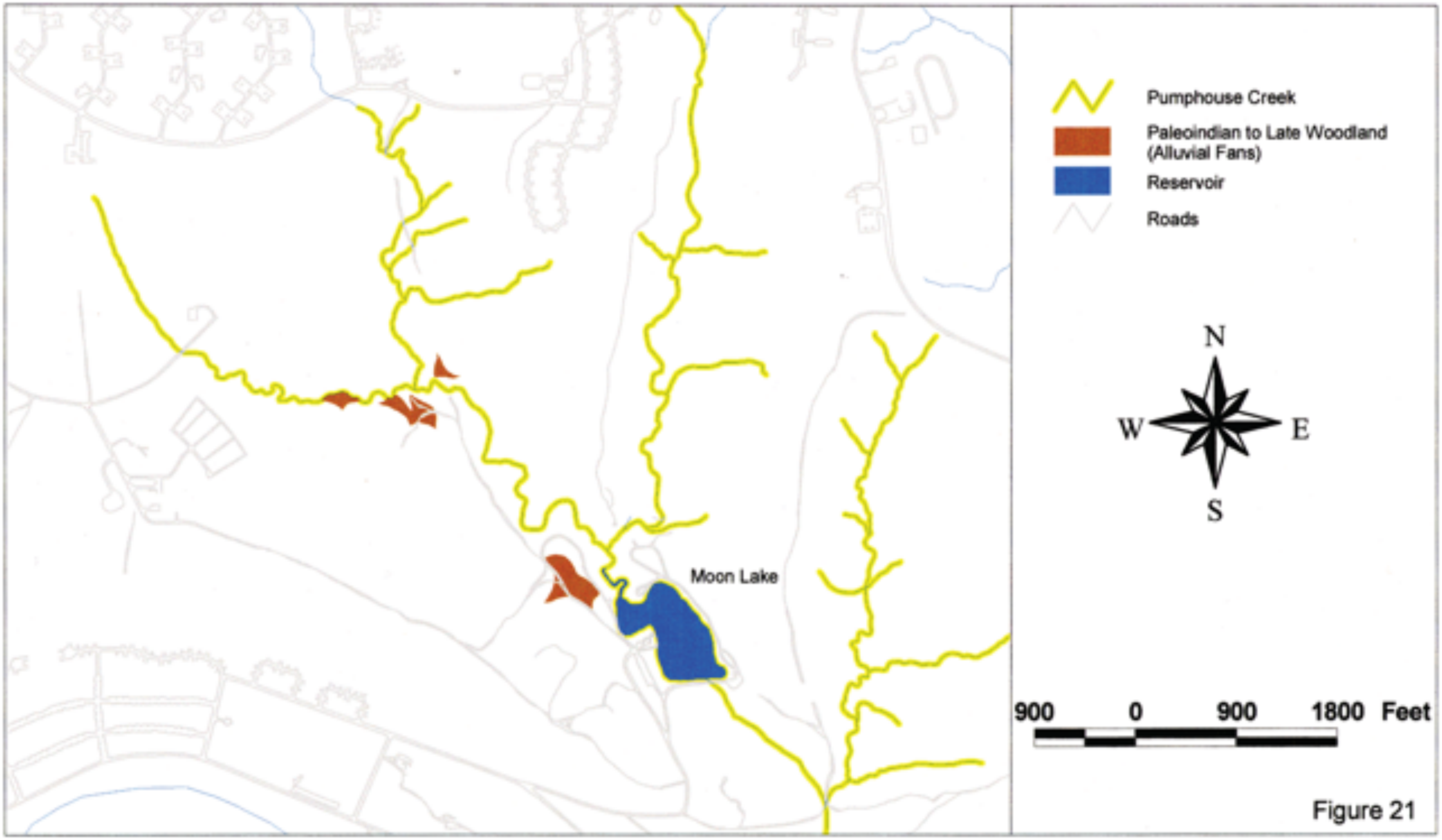


Figure 21

Late Prehistoric to Protohistoric Sediments

Forsyth Creek

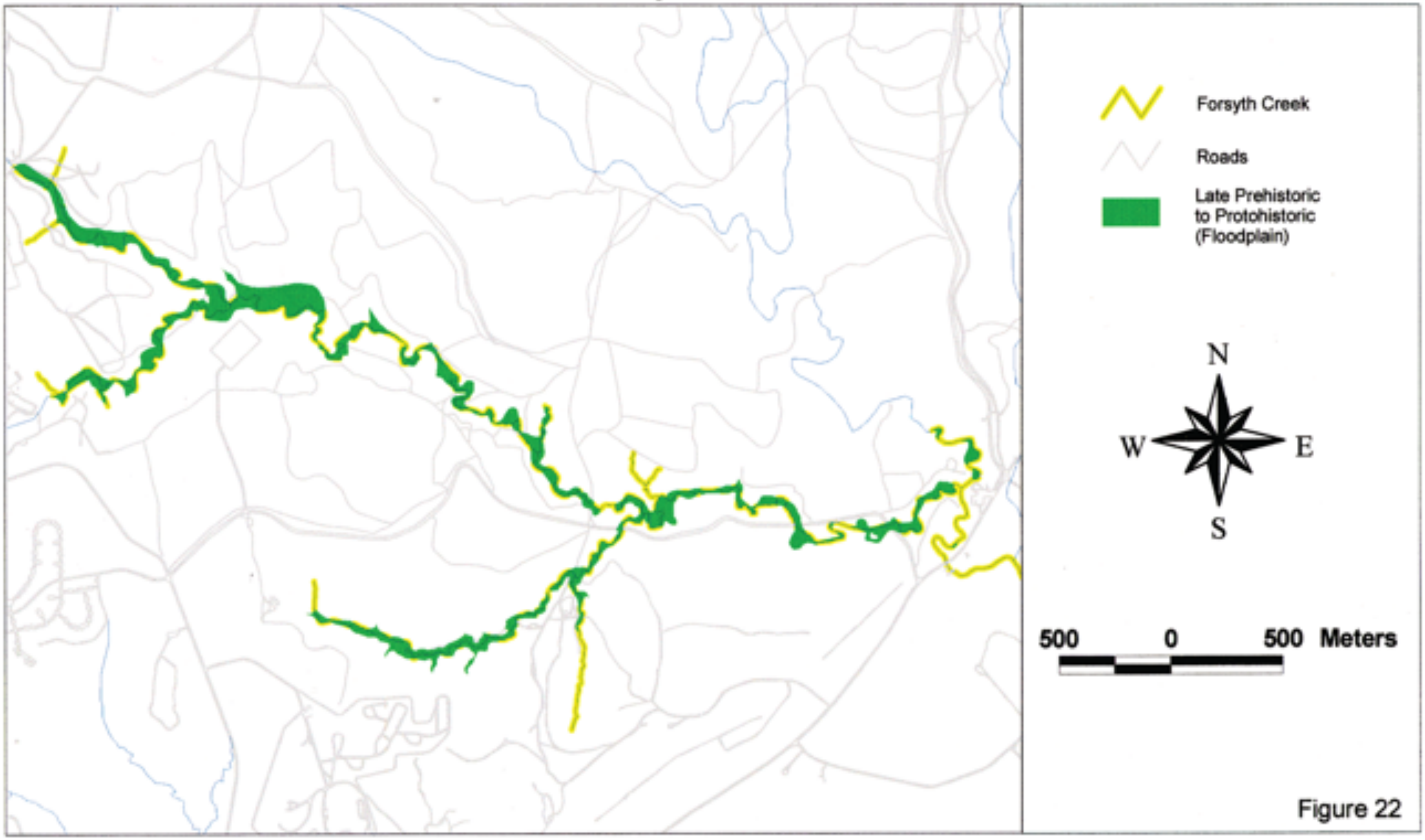


Figure 22

Late Archaic to Late Woodland Sediments

Forsyth Creek

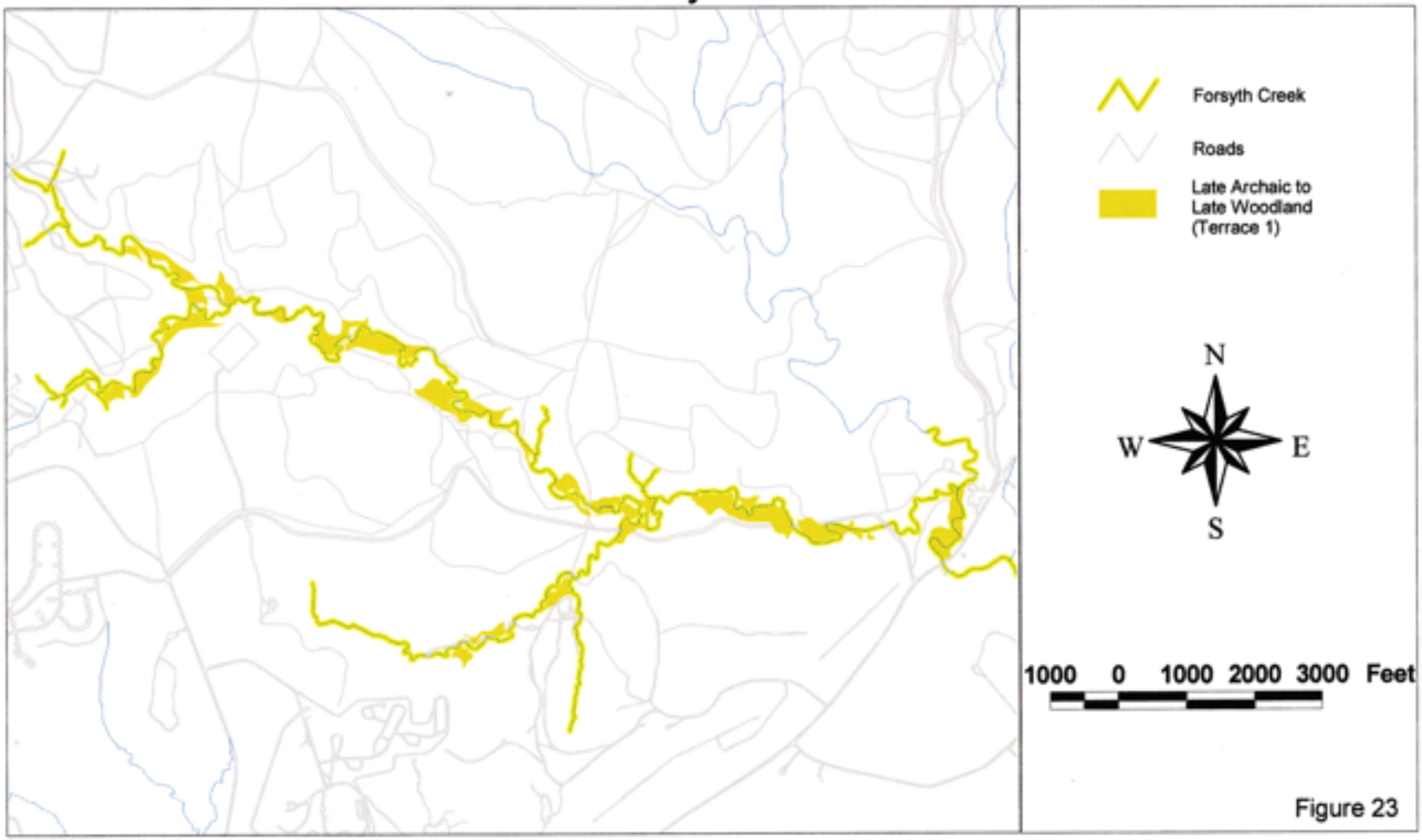


Figure 23

Paleoindian to Middle Archaic Sediments

Forsyth Creek

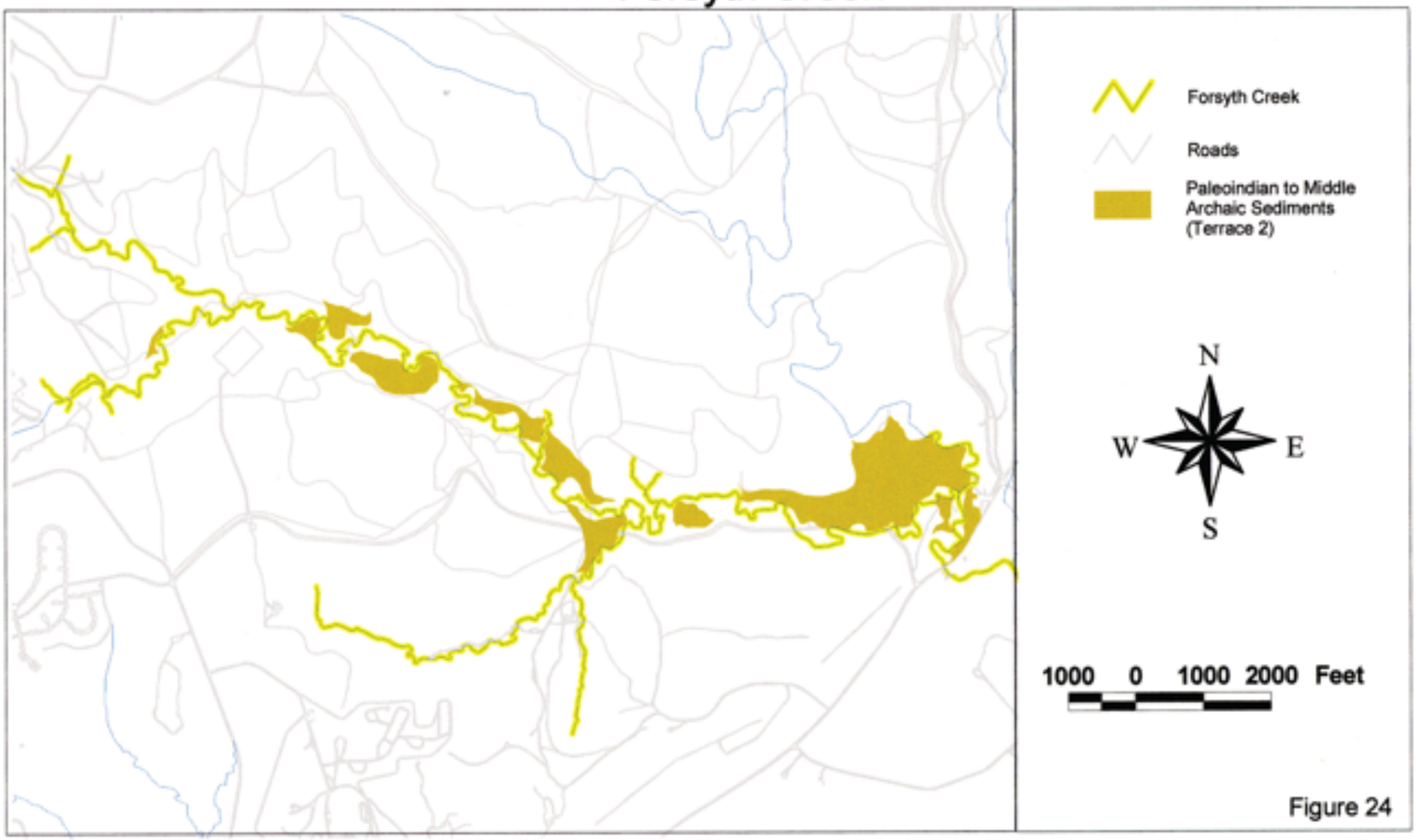


Figure 24

Surficial Sediments

Forsyth Creek

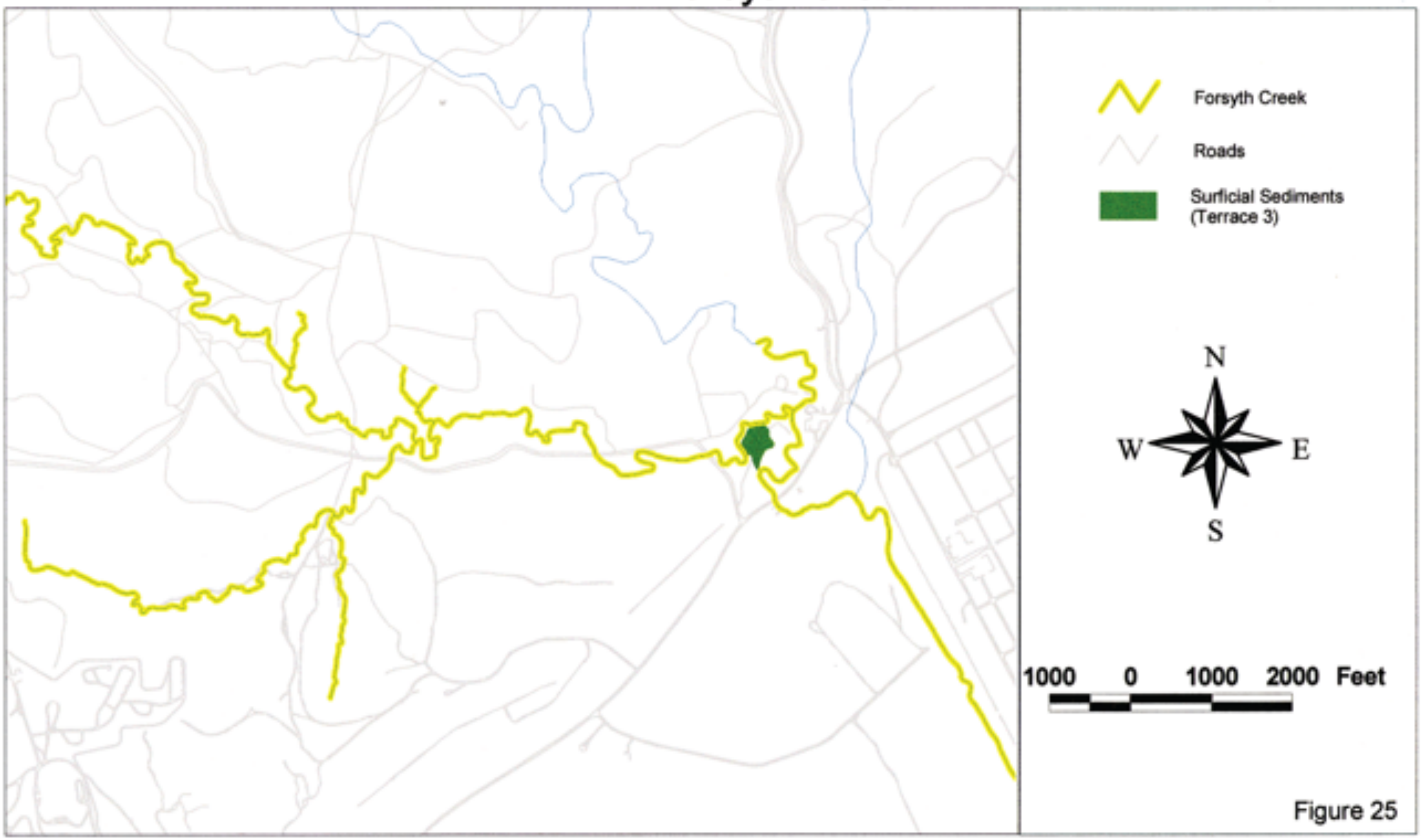


Figure 25

Paleoindian to Early Woodland

Forsyth Creek

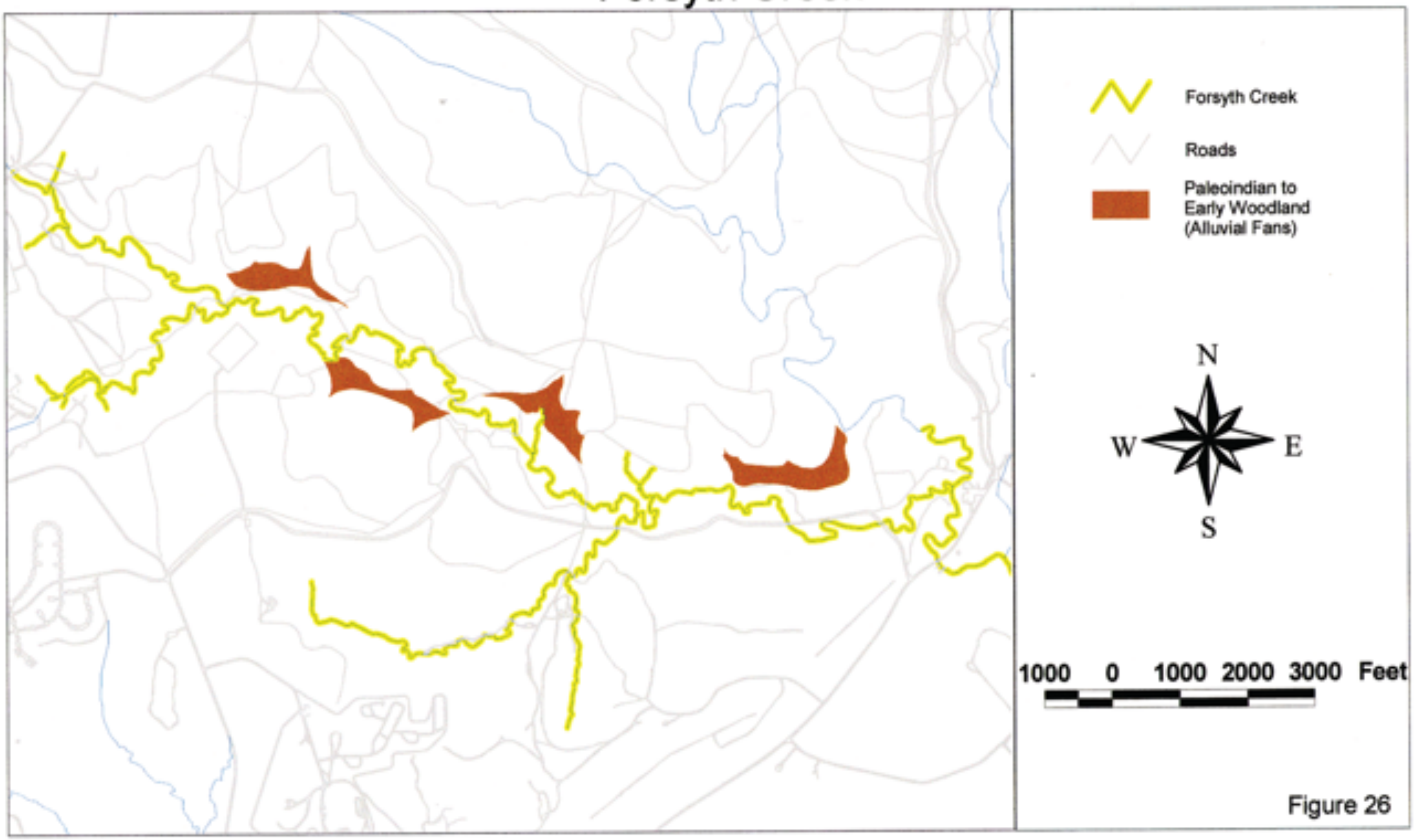


Figure 26

Wildcat Creek. Due to recent, region-wide entrenchment, Wildcat Creek has little expression of flood plain (Fig. 27), but older fills abound. T1 surfaces and fills are common throughout, including the Little Arkansas Creek valley (Fig. 28). T2 fills are, however, ubiquitous, implying that a large potential exists for the presence of buried Paleoindian and Archaic materials in the main valley (Fig. 29). Because of the relatively large extent and age range of alluvial fans in the creek system valley, it is also likely that potential sites are buried in these deposits as well; in fact, the higher and better drained fans may have been preferred surfaces during times of frequent flooding (Fig. 30).

Late Prehistoric to Protohistoric Sediments

Wildcat Creek

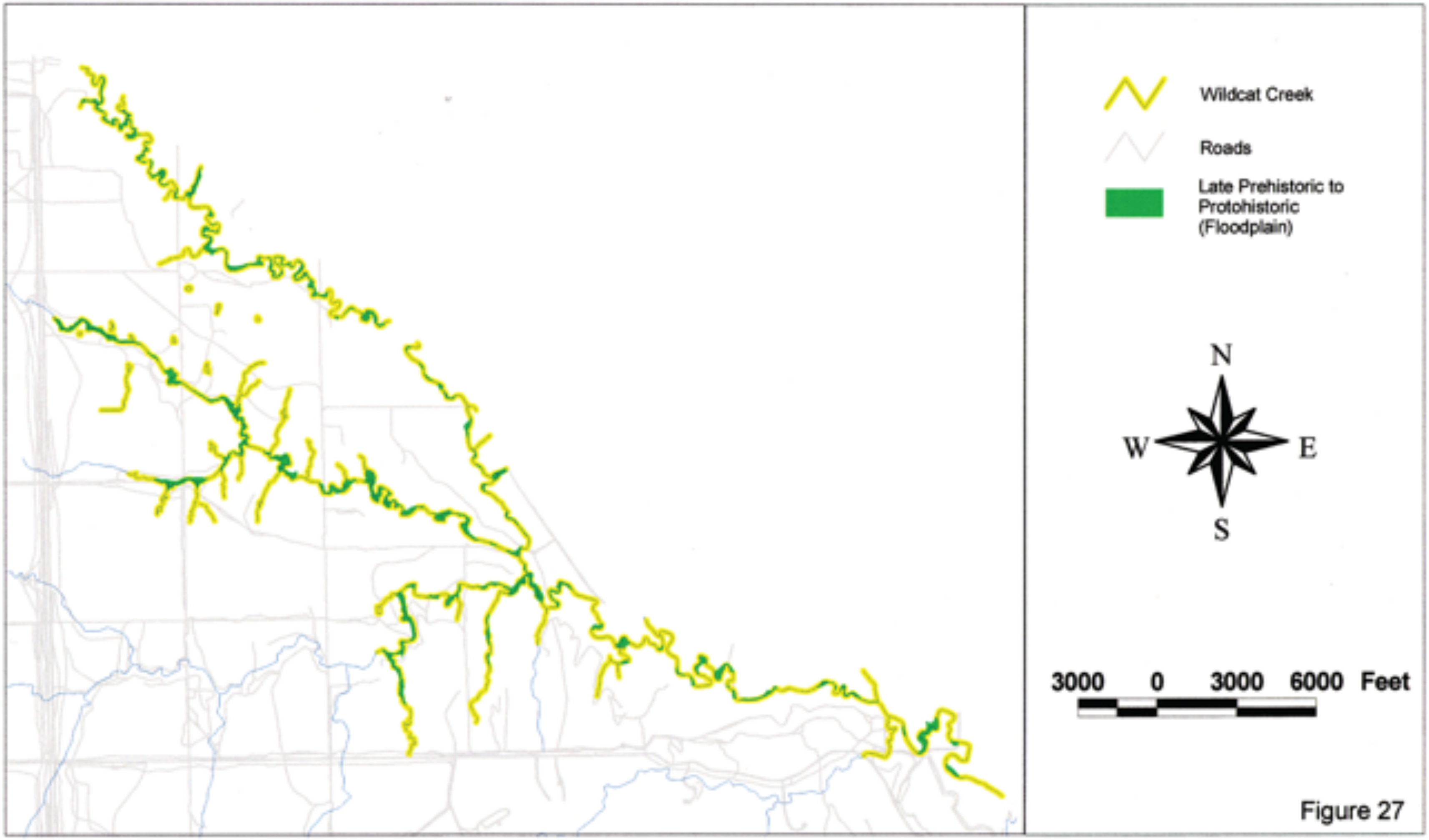


Figure 27

Late Archaic to Late Woodland Sediments

Wildcat Creek

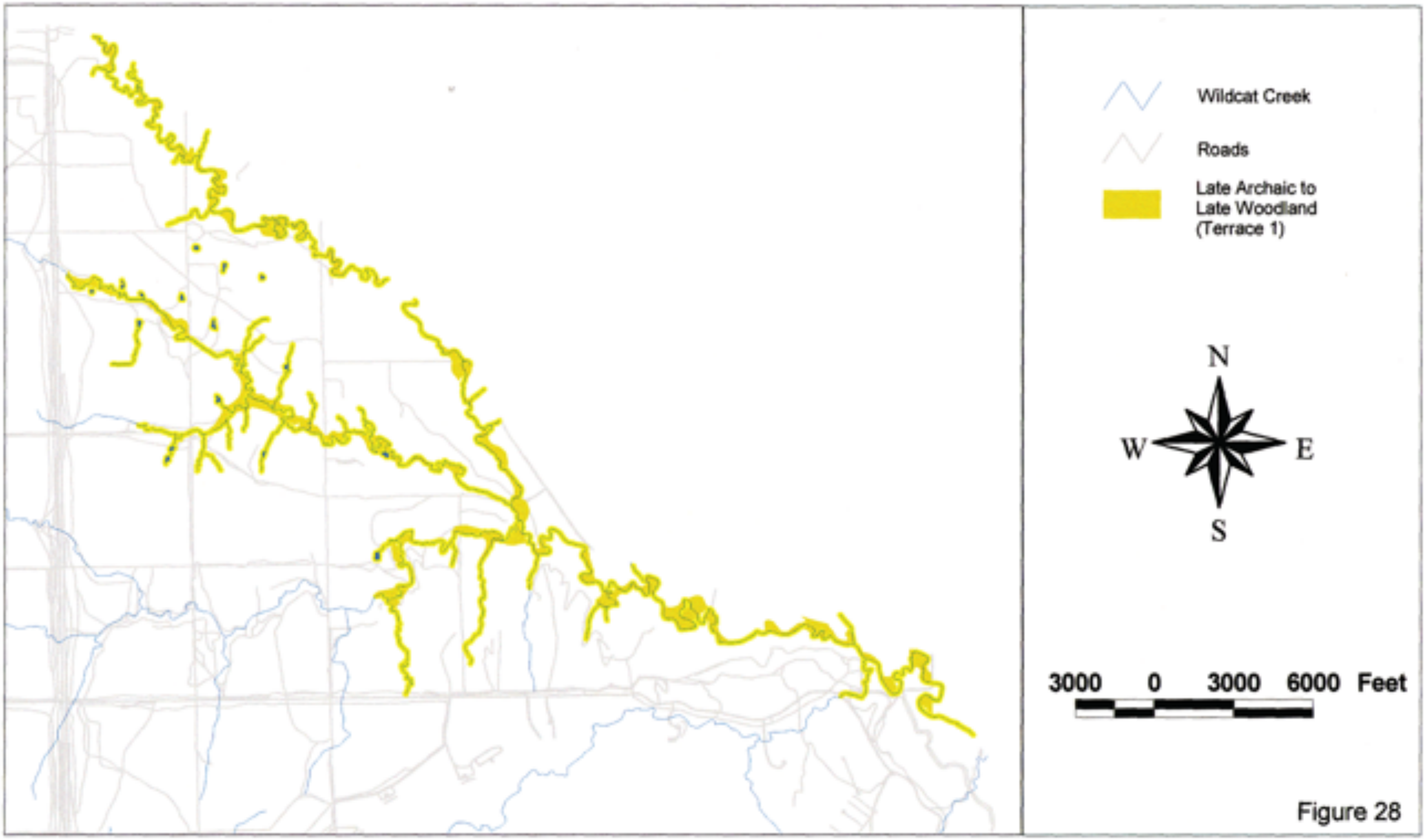


Figure 28

Paleoindian to Late Archaic Sediments

Wildcat Creek

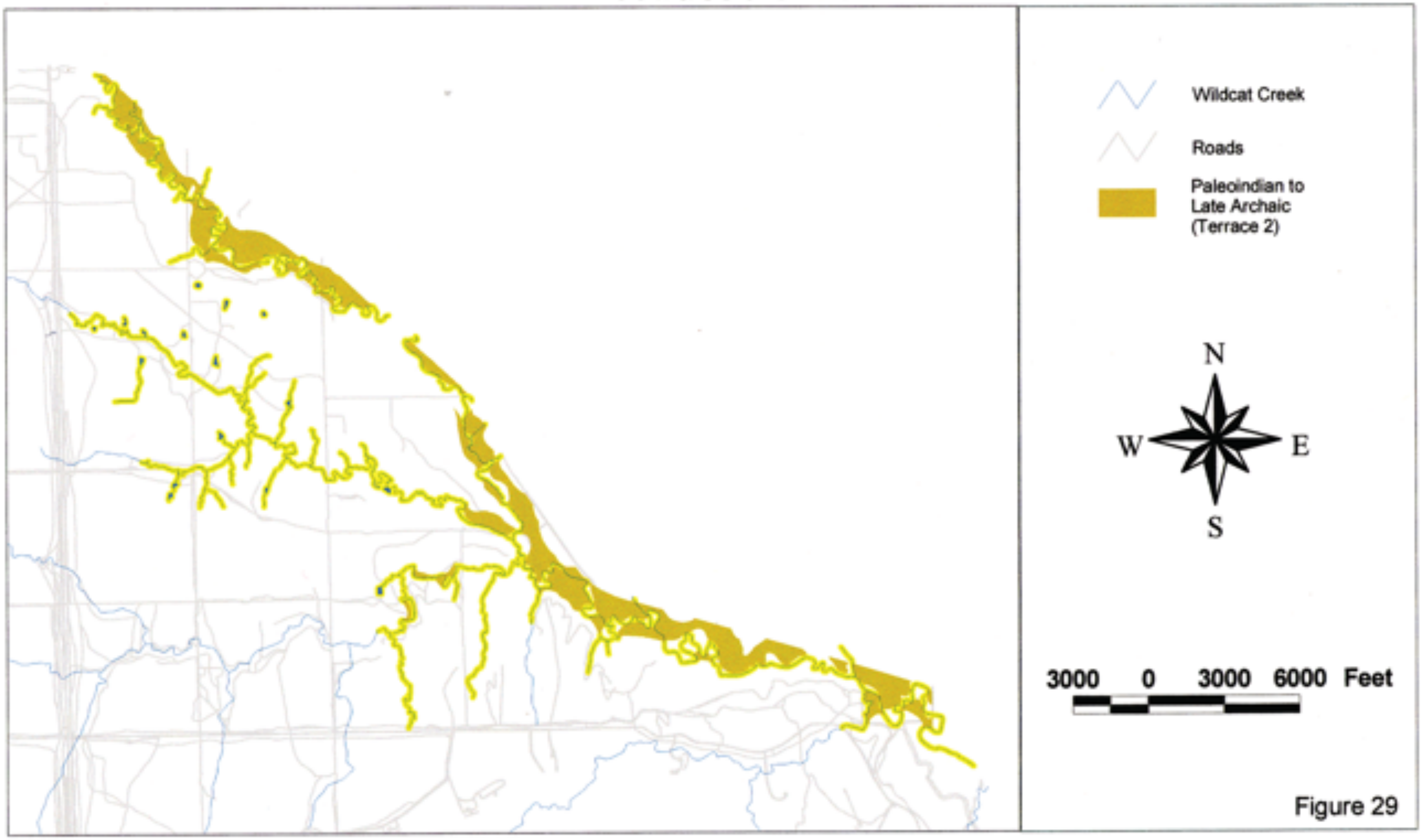


Figure 29

Paleoindian to Late Woodland Sediments

Wildcat Creek

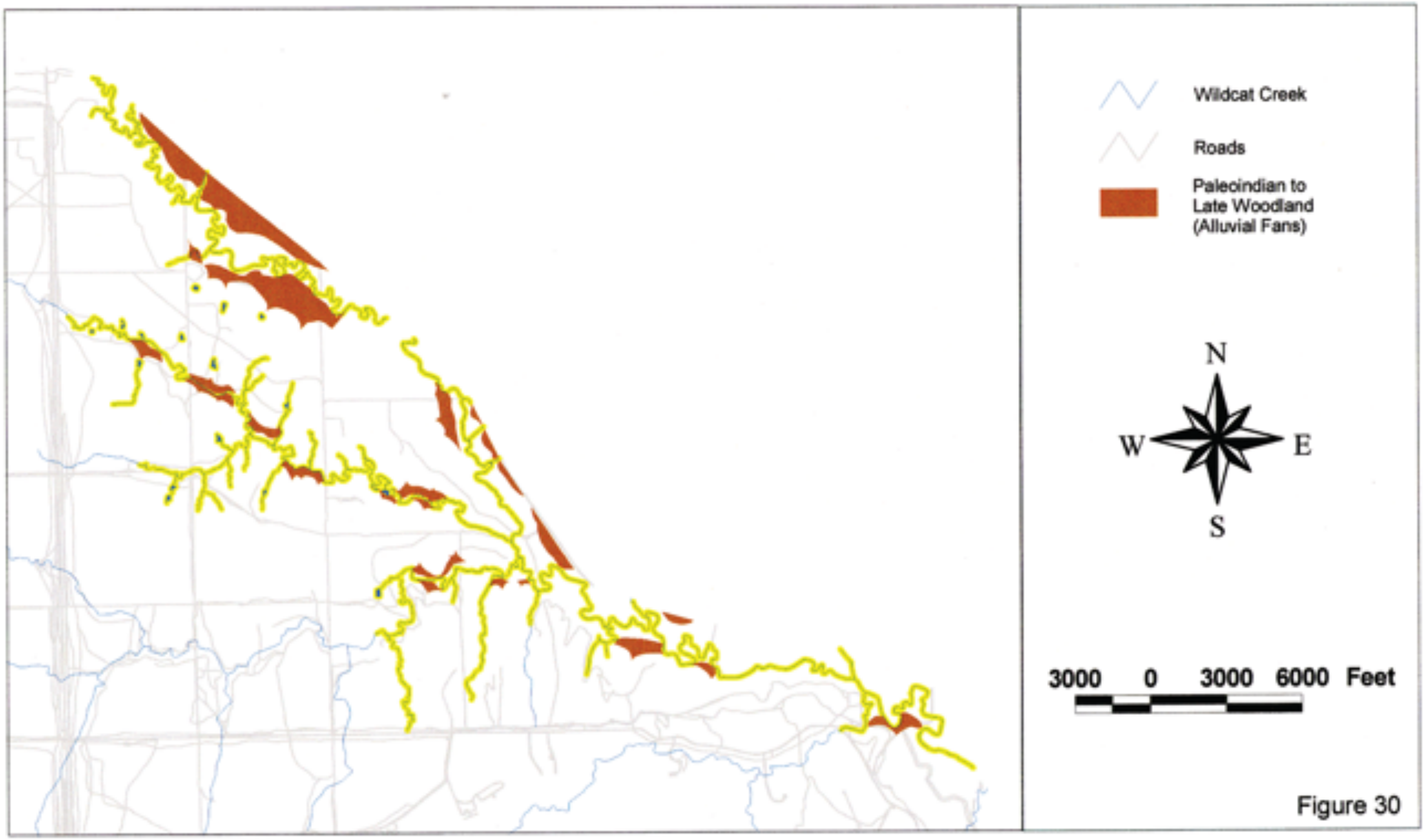
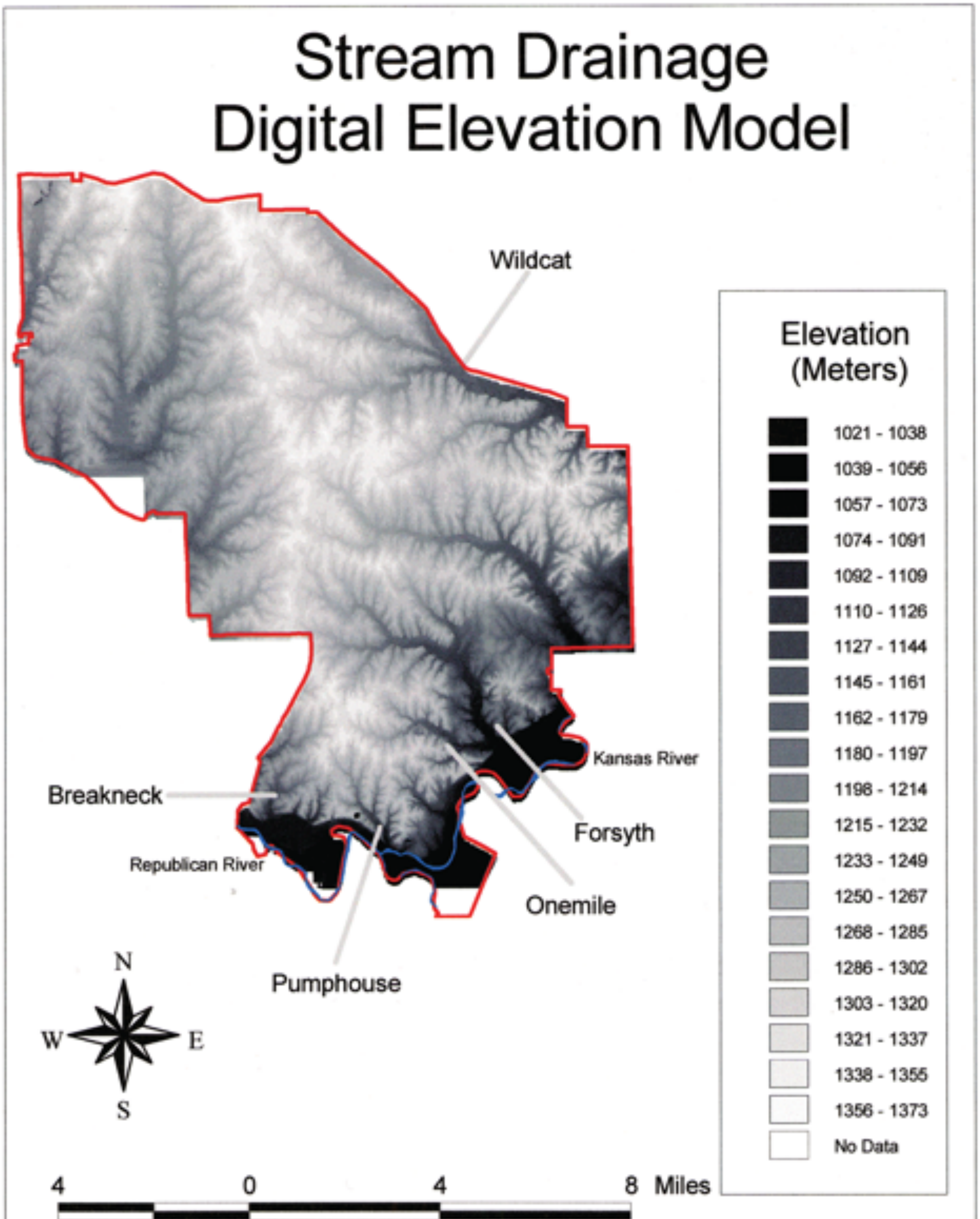


Figure 30

Digitizing and ground-truthing the drainage network

A digital elevation model of the installation depicts the organization of the stream systems and provides insight into the evolution of the landscape. Figure 31 is a small-scale rendering of the installation identifying the stream systems where study emphasis has been focused. Tributaries of the Kansas River have dissected the upland from the southeast and east, whereas the dissection of the Republican River system is evidenced on the western and northwestern realm. Uplands and upper slope reaches are mantled with varying thicknesses of loess, up to 12 m along the Kansas River valley bluffs in the southeast part of the installation. The north-south trending upland divide where dissection of the two systems converges has a loess mantle of variable thickness and is locally known as the "bowling alley" due to its relatively straight and narrow character. Using the electronic version in an ArcView environment, the digital elevation model may be rendered at any scale and the updated drainage network superimposed.

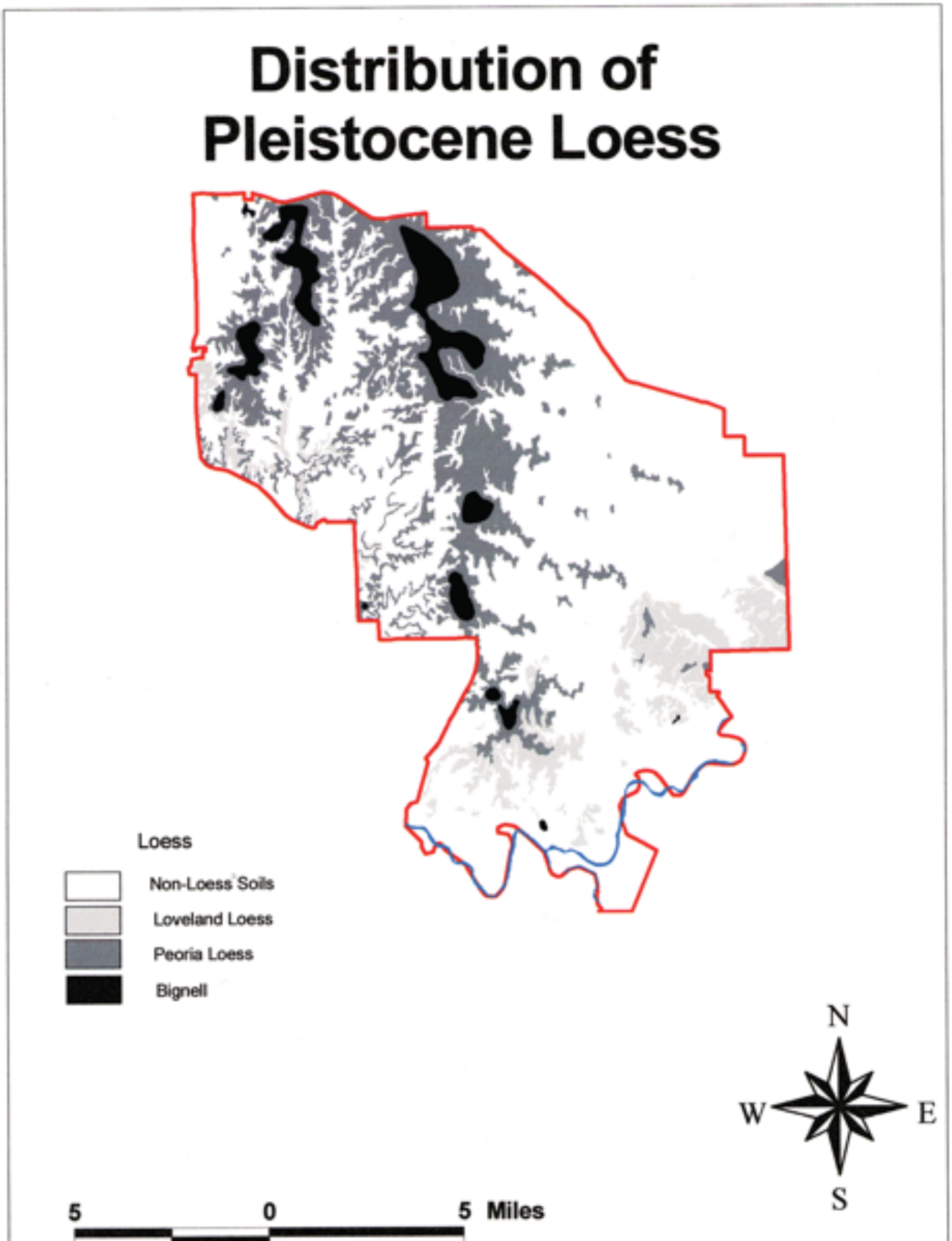


Stream Drainage
Digital Elevation Model
Wildcat
Elevation
(Meters)
1021 - 1038
1039 - 1056
1057 - 1073
1074 - 1091
1092 - 1109
1110 - 1126
1127 - 1144
1145 - 1161
1162 - 1179
1180 - 1197
1198 - 1214
1215 - 1232
1233 - 1249
1250 - 1267
1268 - 1285
1286 - 1302
1303 - 1320
1321 - 1337
1338 - 1355
1356 - 1373
No Data
Kansas River
Breakneck
Forsyth
Republican River
Onemile
Pumphouse
N
W
E
S
4
0
4
8
Miles

Figure 31

Loess distribution

Loveland and Peoria loesses. Distribution of the loessal soils indicates that the primary remnant of the upland loess mantle exists in the western and northern part of the base (Fig. 32). Outcrop of the older Loveland loess occurs, however, in the southeastern part, on the eroded, upper slopes of the steep tributaries to the Kansas River valley, e.g., upper Breakneck, Forsyth, and Onemile creeks, as well as along the valley walls at the upper end of Milford Lake. Peoria loess, topographically and stratigraphically above the Loveland, covers a large expanse along the north-south trending drainage divide in the center of the base, i.e., the “bowling alley.” Areas of Peoria loess not shown on the map, due to errors in the field mapping, occur along the bluff of the Kansas River valley, where thicknesses exceed ten meters in places. Ages on the late Pleistocene loess mantle have been determined at several localities (Table 4).



Distribution of
Pleistocene Loess
Loess
Non-Loess Soils
Loveland Loess
Peoria Loess
Bignell
N
W
E
S
5
0
5 Miles

Figure 32

Table 4. Upland (Loessal) Radiocarbon Ages

Site Name (no.)	Depth (cm)	Material Assayed	ISGS Number	Uncorrected Age	∂¹³C (‰)	Corrected Age
Summer Hill						
Trench 2	215	humates	3164	19,020±650	-15.5	19,170±650
	235	humates	3163	21,440±590	-15.1	21,610±590
	255	humates	3160	21,430±740	-15.4	21,580±740
Trench 5	310	humates	3159	20,610±750	-16.0	20,760±750
	330	humates	3158	22,440±992	-17.0	22,560±990
	350	humates	3157	22,850±100	-17.2	23,000±1,100
Trench 6	150	humates	3101	6,000±130	-16.2	6,140±130
	170	humates	3140	7,640±220	-17.1	7,770±220
	200	humates	3142	11,100±310	-16.8	11,230±310
	240	humates	3131	11,840±270	-16.2	11,980±270
	260	humates	3143	13,080±310	-15.9	13,240±310
	280	humates	3146	13,310±430	-15.6	13,470±430
Trench 6a	90	humates	4174	4,740±70	-14.9	4,900±70
	130	humates	3666	5,960±120	-17.2	6,080±120
	170	humates	3665	8,520±140	-17.3	8,650±140
	210	humates	3731	11,300±220	-17.4	11,430±150
	225	humates	3663	15,290±220	-17.2	15,420±220
	256	humates	3750	14,690±240	-17.3	14,810±240
	295	humates	3749	17,320±310	-16.5	17,460±310
	330	humates	3748	17,260±300	-16.0	17,400±300
	344	humates	3747	17,040±300	-15.9	17,180±300

Site Name (no.)	Depth (cm)	Material Assayed	ISGS Number	Uncorrected Age	∂13C (‰)	Corrected Age
Lookout Hill						
Core 23	100	humates	3010	3,750±160	-16.0	3,890±160
Pumphouse Hill						
	80	humates	3777	3,200±70	-14.2	3,380±70
	105	humates	3776	4,250±80	-14.9	4,410±80
	130	humates	3165	5,660±180	-15.6	5,810±180
	170	humates	3728	7,210±130	-16.2	7,350±130
	235	humates	3729	12,190±250	-16.6	12,330±250
	265	humates	3730	16,280±220	-21.8	16,330±220
	290	humates	3167	18,770±450	-21.6	18,830±450
	290	humates	3727	21,670±670	-22.2	21,720±670
	330	humates	3166	22,910±850	-18.4	23,010±850
	340	humates	3618	33,210±2700	-18.0	33,300±2,700
Site 27						
	64	humates	3779	3,300±70	-15.7	3,450±70
	129	humates	3616	9,350±100	-20.5	9,420±100
	190	humates	3615	17,730±320	-21.1	16,790±320
	234	humates	3614	21,180±150	-18.2	21,290±150
Farnum Creek So(site 28)						
	18	humates	3058	900±130	-15.7	1,050±130
	23	humates	3005	850±100	-15.5	1,000±100
	28	humates	3006	1,570±110	-15.4	1,730±110
	147	humates	3008	14,050±770	-19.0	14,140±770
	172	humates	3055	13,990±470	-17.3	14,120±470

Site Name (no.)	Depth (cm)	Material Assayed	ISGS Number	Uncorrected Age	∂13C (‰)	Corrected Age
	177	humates	3057	19,540±1800	-17.6	19,700±1,800
	202	humates	3007	14,980±590	-17.3	15,110±590
Bala Cemetery						
Core 19	150	humates [1]	2622	18,950±280	-17.3	19,070±280
Trench	147	humates	3613	16,300±150	-22.6	16,340±150
	194	humates	3612	21,170±140	-20.3	21,240±140
	220	humates	3611	25,310±320	-18.3	25,420±320
	253	humates	3610	28,010±280	-17.1	28,140±280
1. sample not treated with 2N hot HCl						

Bignell loess. Determining the distribution of the Bignell loess is difficult in that it has no unique soil series associated with it. This is not surprising in that the Bignell loess is very similar to the Peoria loess and, where thin, it becomes completely involved in surface soil development. A general model for its distribution has emerged, however: the Bignell is typically found on the highest areas of major drainage divides and at scattered locations along the bluff of the Kansas River valley (Fig. 33). The distribution indicated in the northern part of the Bowling Alley has not been ground-truthed due to its inaccessibility (firing range). It has, however, been located by soil coring along the northern and northwestern parts adjacent to the range. Six sites (3 major divides, 3 bluff) have documented the existence and age of the Brady soil and overlying Bignell loess; data from each of these sites is available in W.C. Johnson, 1998a, b, and in Table 4.

Distribution of Holocene Loess

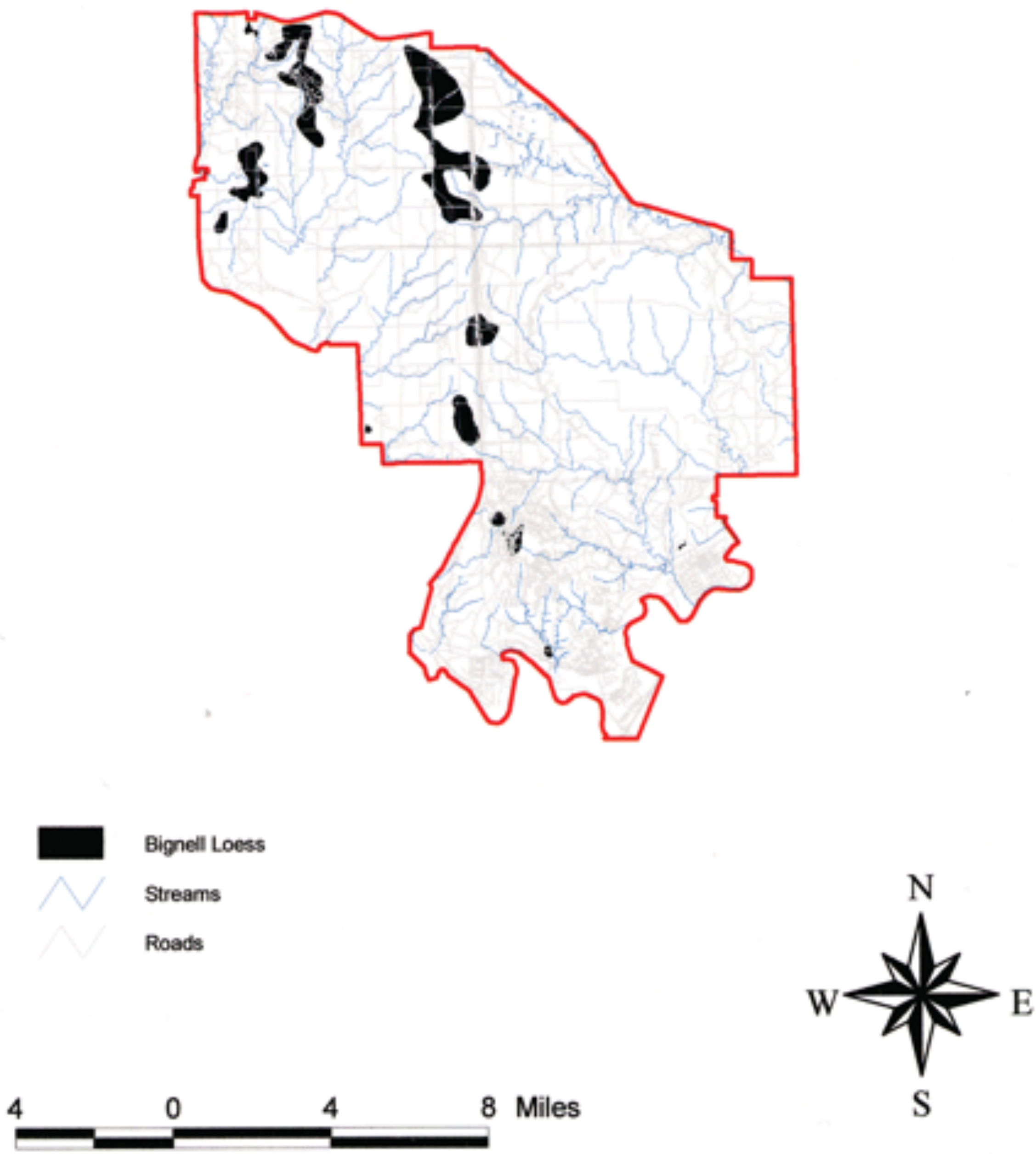


Figure 33

Other discrete landforms and sedimentary bodies

Consideration of landforms other than valley fills and the sedimentary bodies comprising the upland loess mantle provides insight into the exposed and near-surface bedrock expression on the installation. Areas not mantled by loess (Fig. 32) and filled with alluvium (Fig. 31) consist of valley side slope deposits, containing admixtures of loess and weathered bedrock. Bedrock exposures are most common in the southeastern part of the installation and are manifest as outcrops in the upper parts of small, steep tributaries.

Task Three: Three-Dimensional Visualization of Landform Sediment Assemblages

Oblique, three dimensional views of the alluvial fill surfaces were generated in order to provide a perspective on the present-day valley-bottom topography. This task was accomplished using ESRI ArcView 3-D Analyst software. In addition, DeLorme 3-D TopoQuad databases and software were used to generate low, oblique images of the study drainage basins.

Three-dimensional imaging of stream valley alluvial surfaces

Using vertical exaggeration and oblique orientation, study stream systems are depicted to illustrate the proportional differences in elevation between the different alluvial surfaces, i.e., the flood plain and terraces. Onemile Creek fill consists largely of the recent flood plain deposits, but yet contains several large fragments of T1 and T2 fill, in addition to a major alluvial fan (Fig. 34; refer to the color scheme-surface correlations used in Figs. 3-17). In contrast, another small stream system, Breakneck Creek, contains little of the recent flood plain fill; T2 fill and alluvial fan fill dominate (Fig. 35). This system therefore has an appreciably higher percentage of older fill than Onemile Creek. A larger system, Pumphouse Creek, has little flood plain fill and is dominated by T1 and T2 fill (Fig. 36). Upper and lower Forsyth Creek is dominated by T2 fill and large alluvial fans (Fig. 37). The large body of T2 fill in lower Forsyth Creek (at its confluence with Threemile Creek) contains, as noted above, evidence of an apparent heavy concentration of late Paleoindian and early Archaic cultural activity. The largest stream system studied on the installation (other than the Kansas and Republican Rivers), Wildcat Creek, is split into four separate 3-D images (Fig. 38). Upper wildcat Creek is dominated by alluvial fans and by T2 fill (Fig. 39). The alluvial fans have determined the course of the meander plain by serving to deflect the channel toward the opposite valley wall. The Little Arkansas Creek also has been dominated and controlled by alluvial fan development and growth, a process that has probably persisted for the last 20,000 years or more, as evidenced from the radiocarbon ages determined from fan fill (Fig. 39). The middle reach of Wildcat Creek is similarly dominated by T2 fill and to a lesser extent by alluvial fans (Fig. 40), as is the lower part of Wildcat Creek (Fig. 40).

Onemile Creek

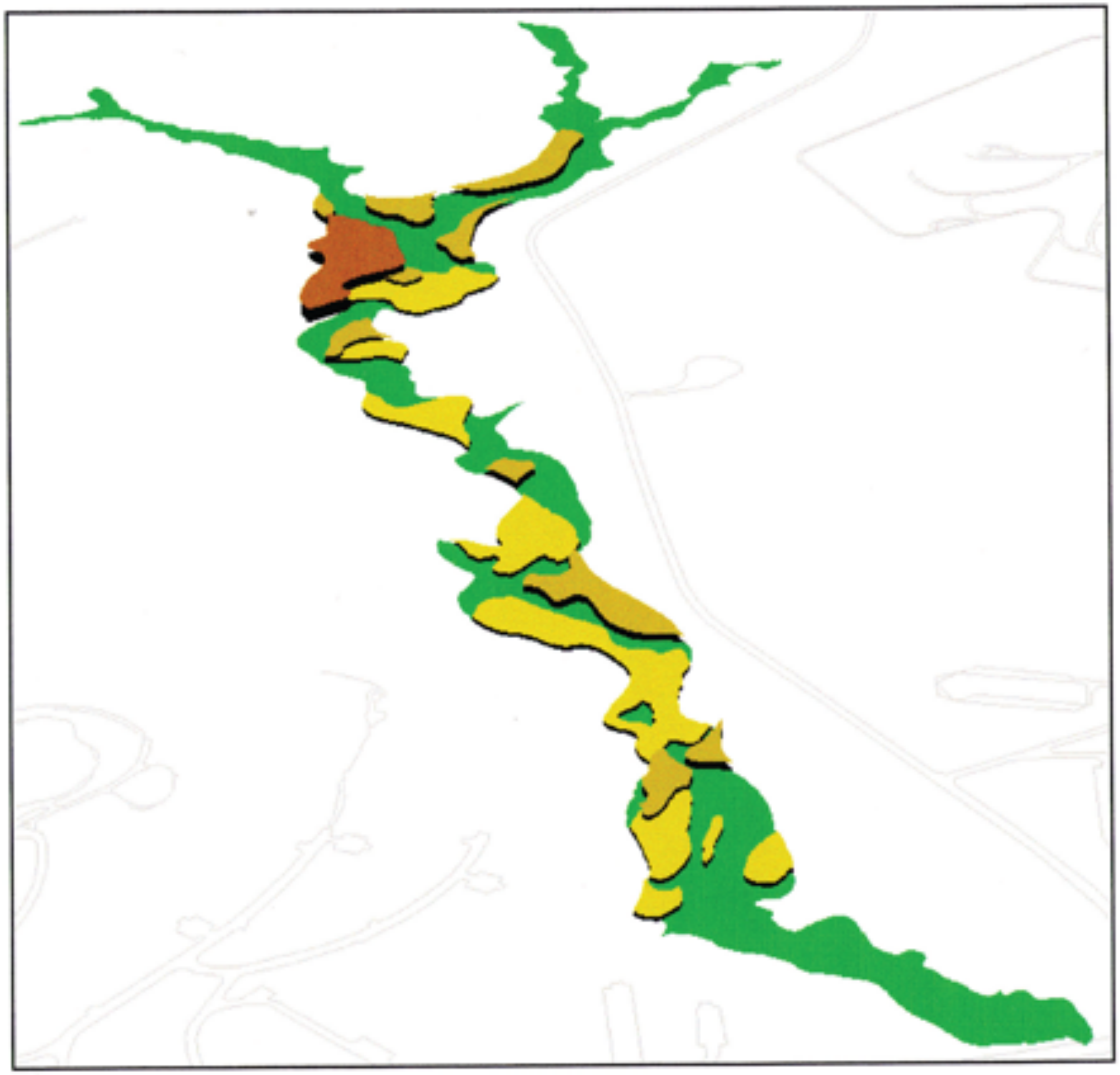


Figure 34

Breakneck Creek

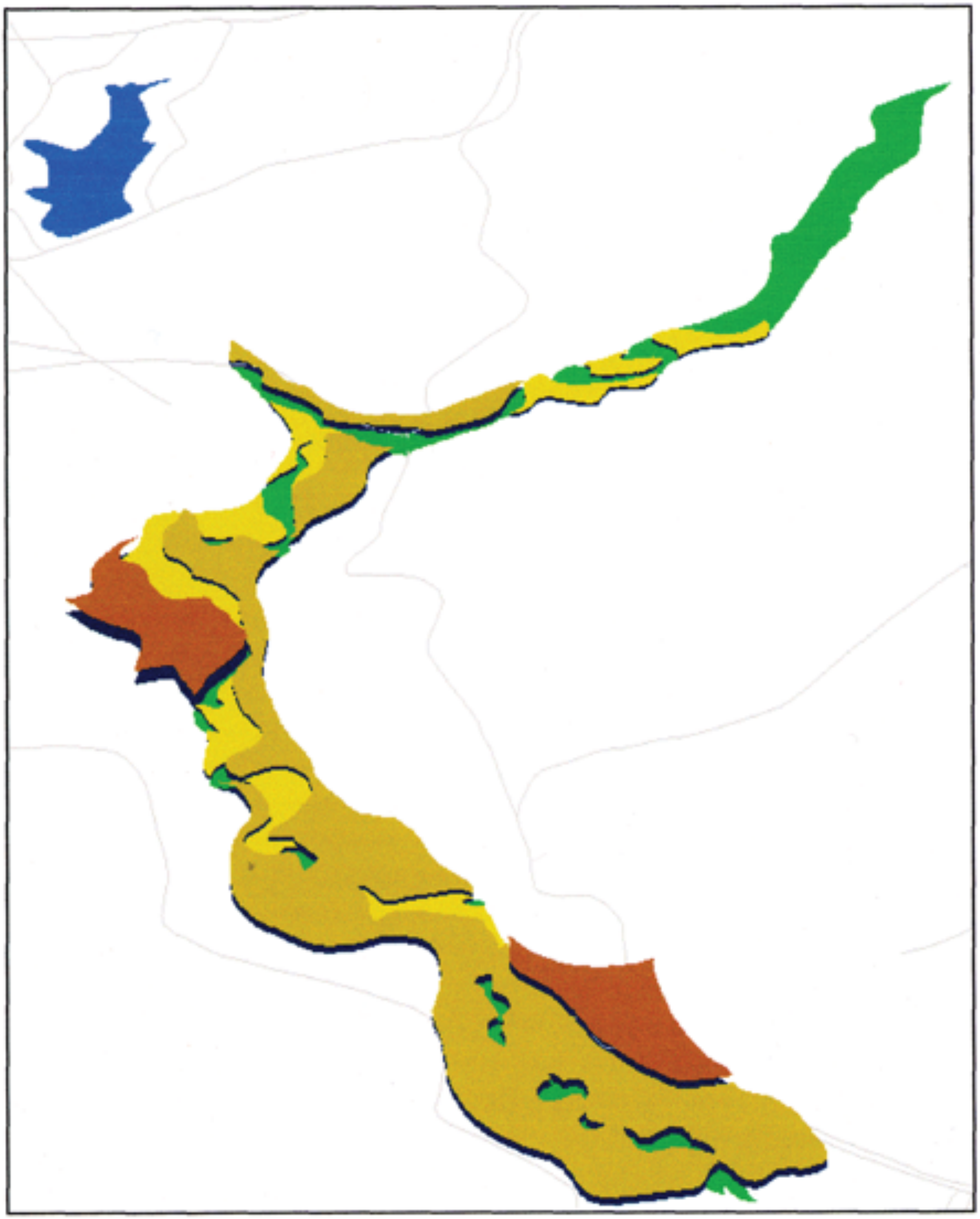
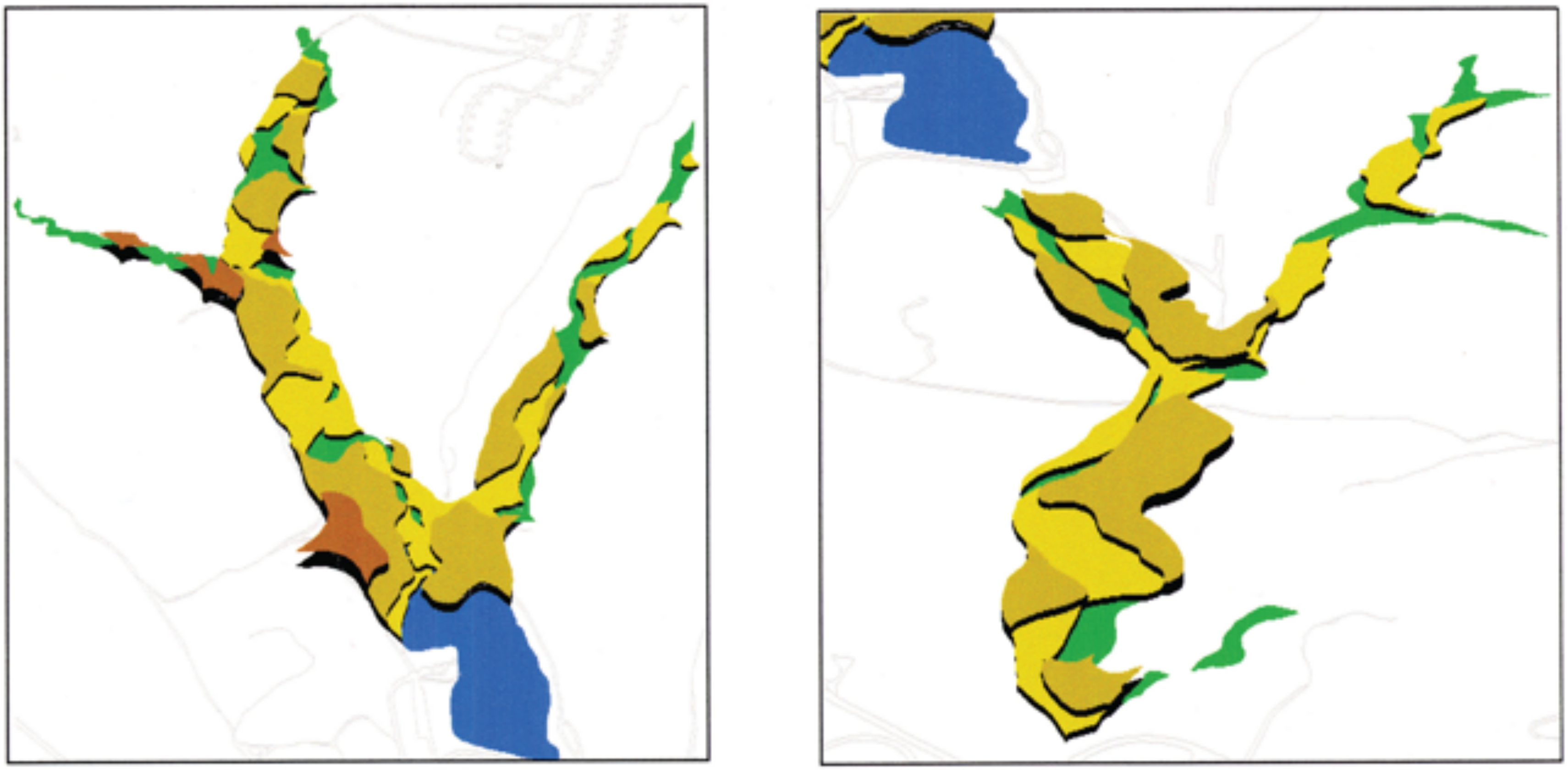


Figure 35

Pumphouse Creek

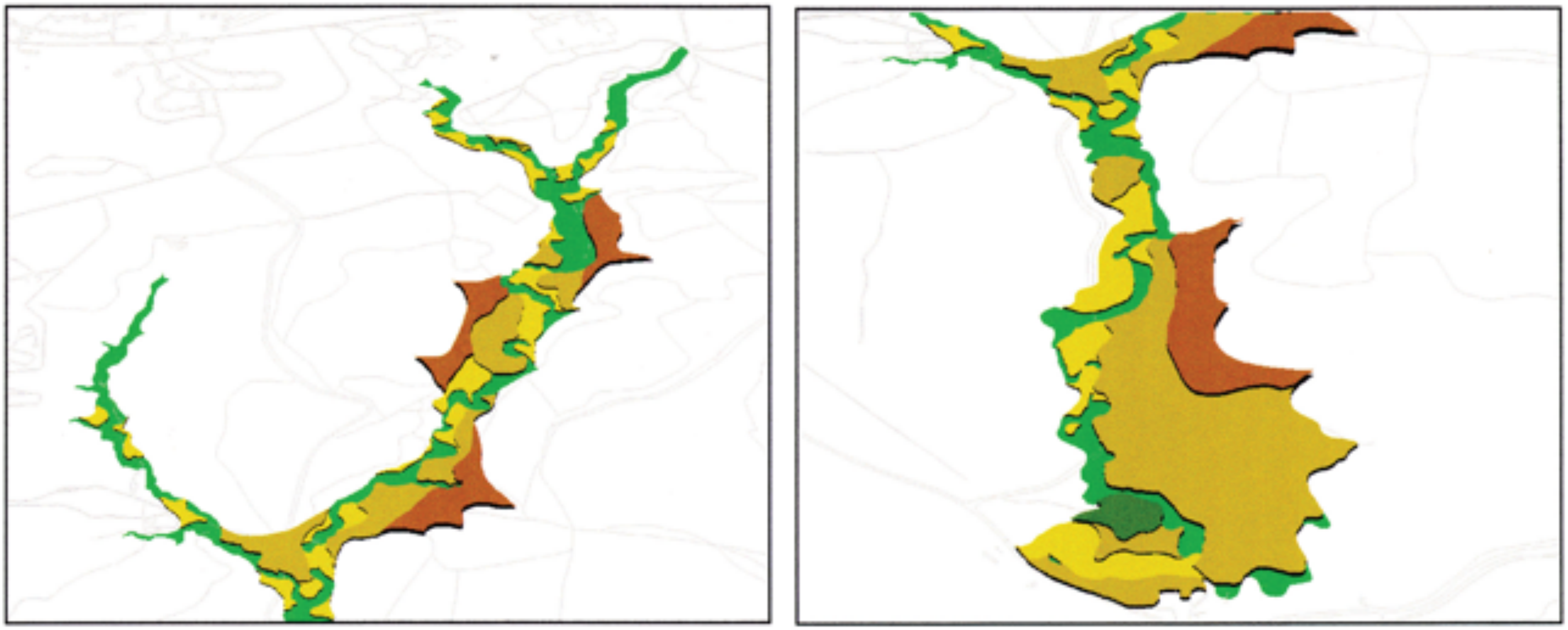


A. Upper

B. Lower

Figure 36

Forsyth Creek

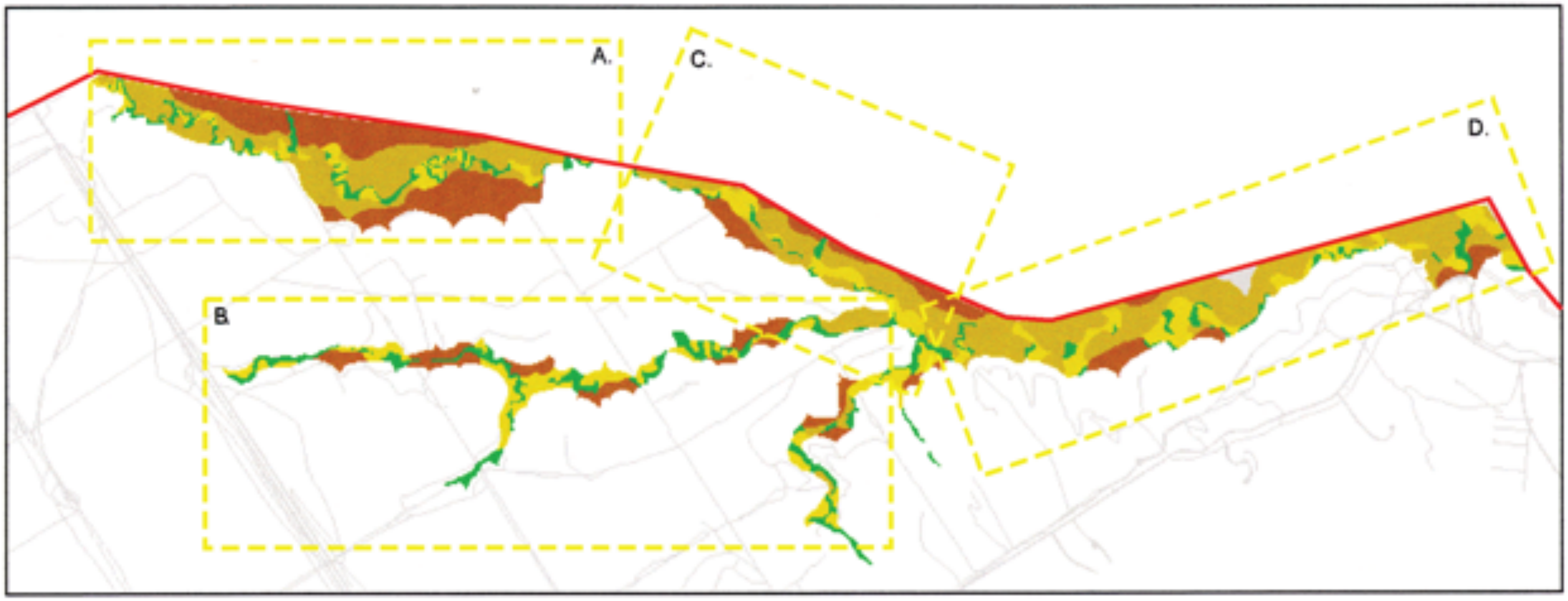


A. Upper B. Lower

Figure 37

3-Dimensional Rendering of Wildcat Creek

Index Map



A. Upper

B. Little Arkansas Creek

C. Middle

D. Lower

Figure 38

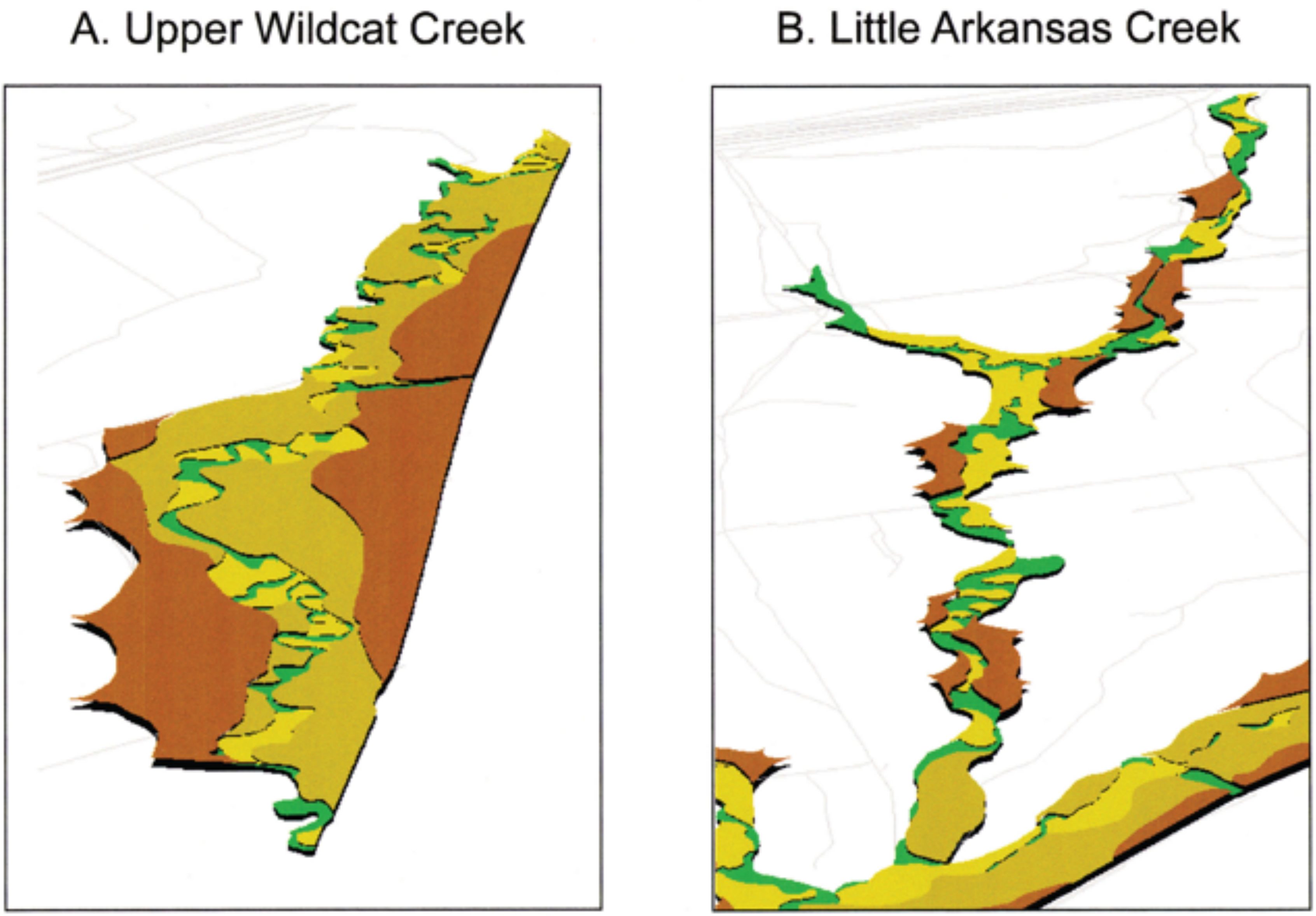


Figure 39

C. Middle Wildcat Creek

D. Lower Wildcat Creek

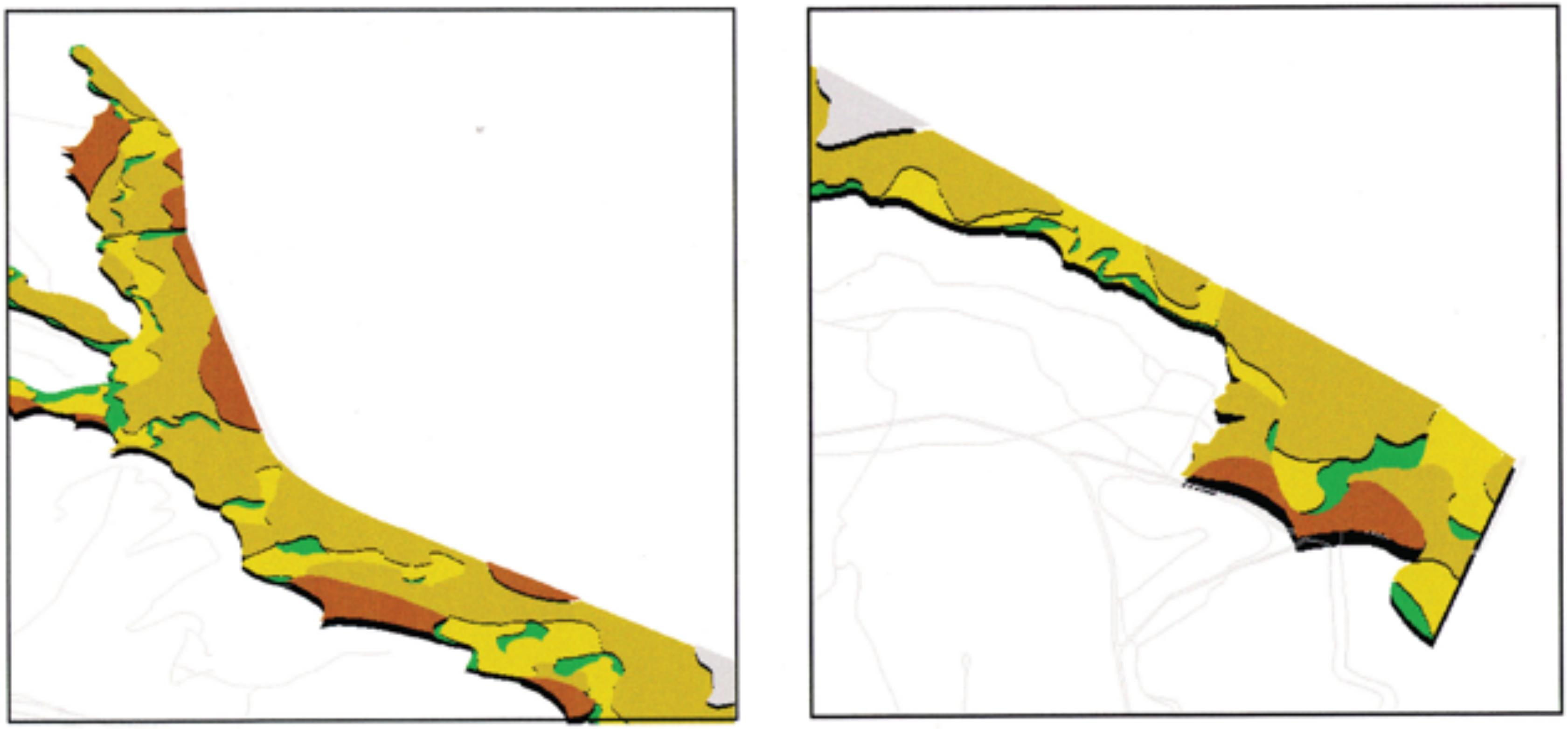
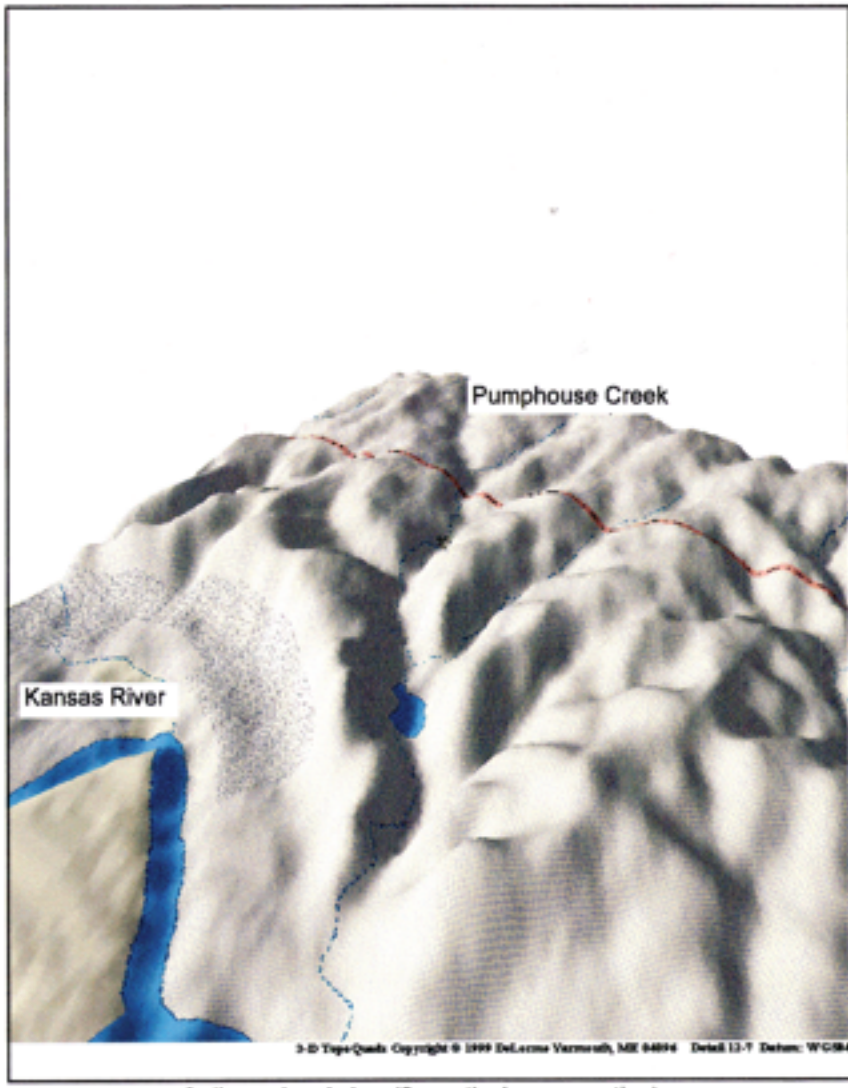


Figure 40

Three-dimensional imaging of stream drainage basins

Low-oblique, three-dimensional imaging effects provide a perspective on the stream basins as a whole, rather than only on the valley fills as in figures above. The isolated, high-gradient nature of Pumphouse Creek gives it a canyon-like setting (Fig. 41), which would likely have been attractive to aboriginal peoples due to the microenvironment and seclusion, but yet proximity to the Kansas River valley and it associated resources. Forsyth Creek basin would have provided the same attributes as Pumphouse Creek basin, but would have afforded the opportunity for cultivation of its wide valley bottom and gentle side slopes (Fig. 42). The many cultural resources and travel corridor that Wildcat Creek provided aboriginals is apparent (Figs. 43, 44). In addition, it possesses the major and minor tributary valleys, which offer seclusion and other unique attributes.

Pumphouse Creek

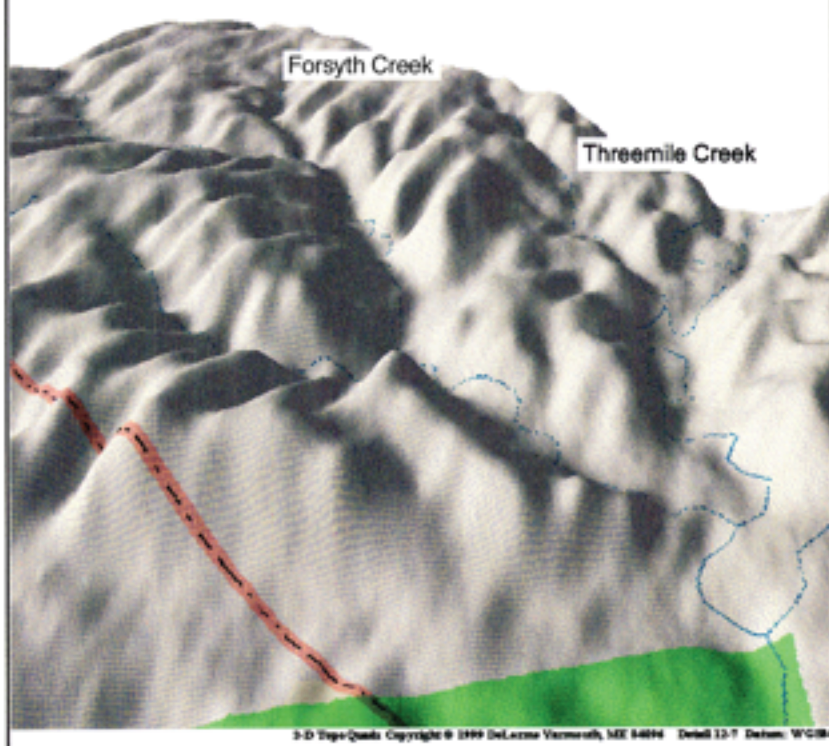


3-dimensional view (8x vertical exaggeration)

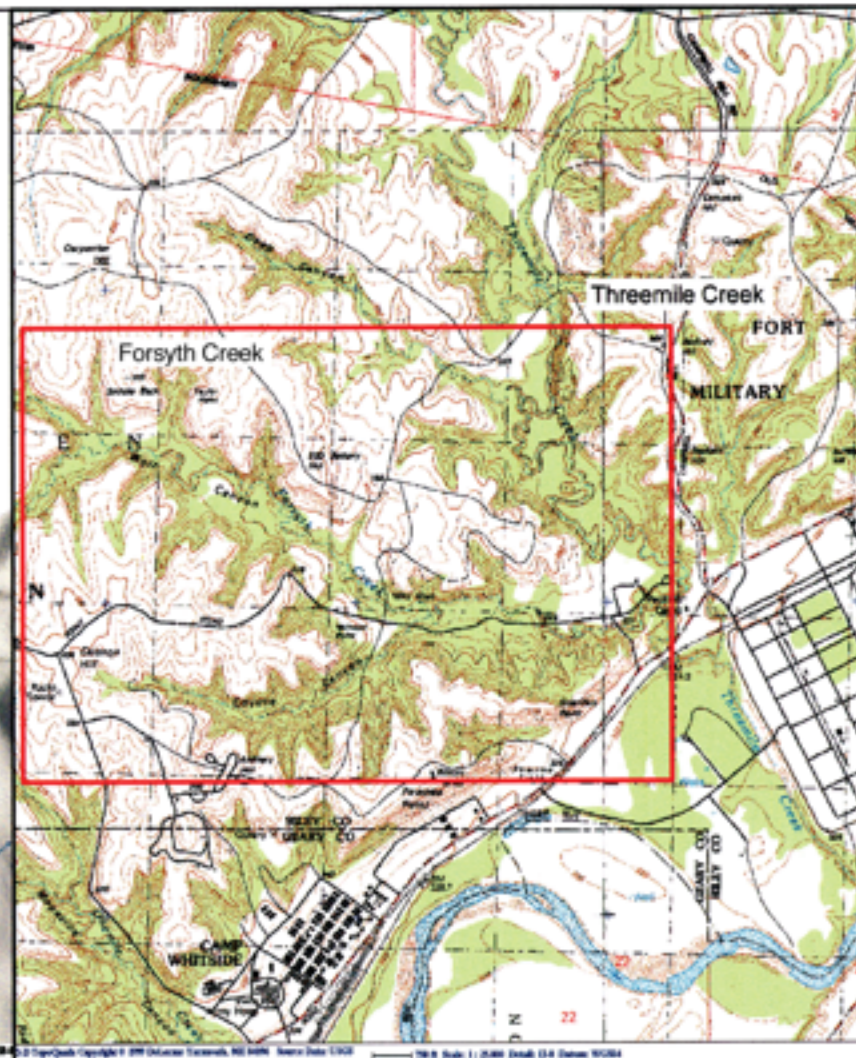
USGS Topographic Quadrangle

Figure 41

Forsyth Creek



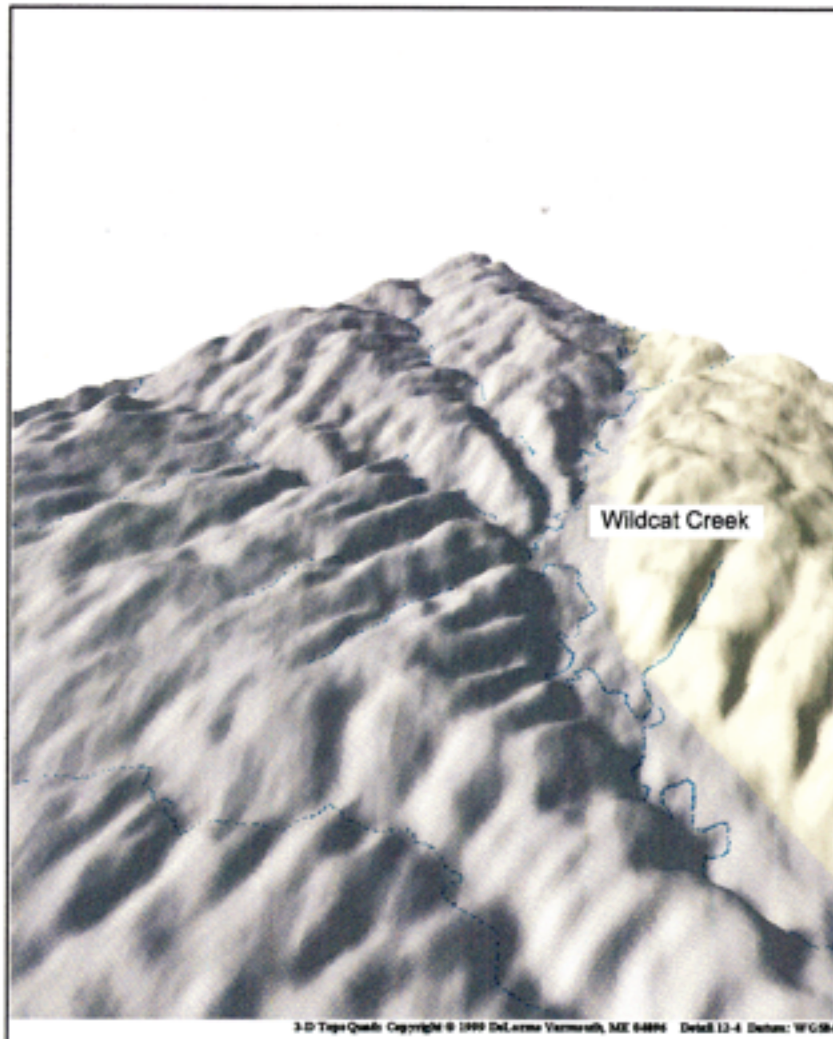
3-dimensional view (8x vertical exaggeration)



USGS Topographic Quadrangle

Figure 42

Wildcat Creek

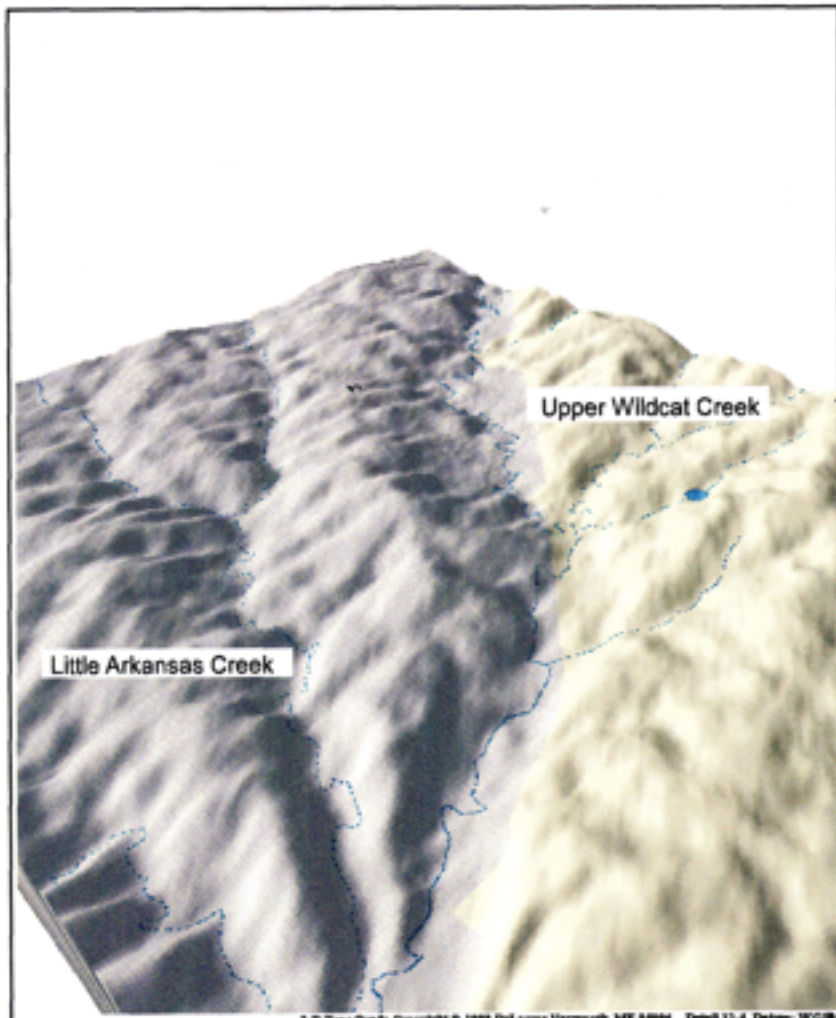


3-dimensional view (8x vertical exaggeration)

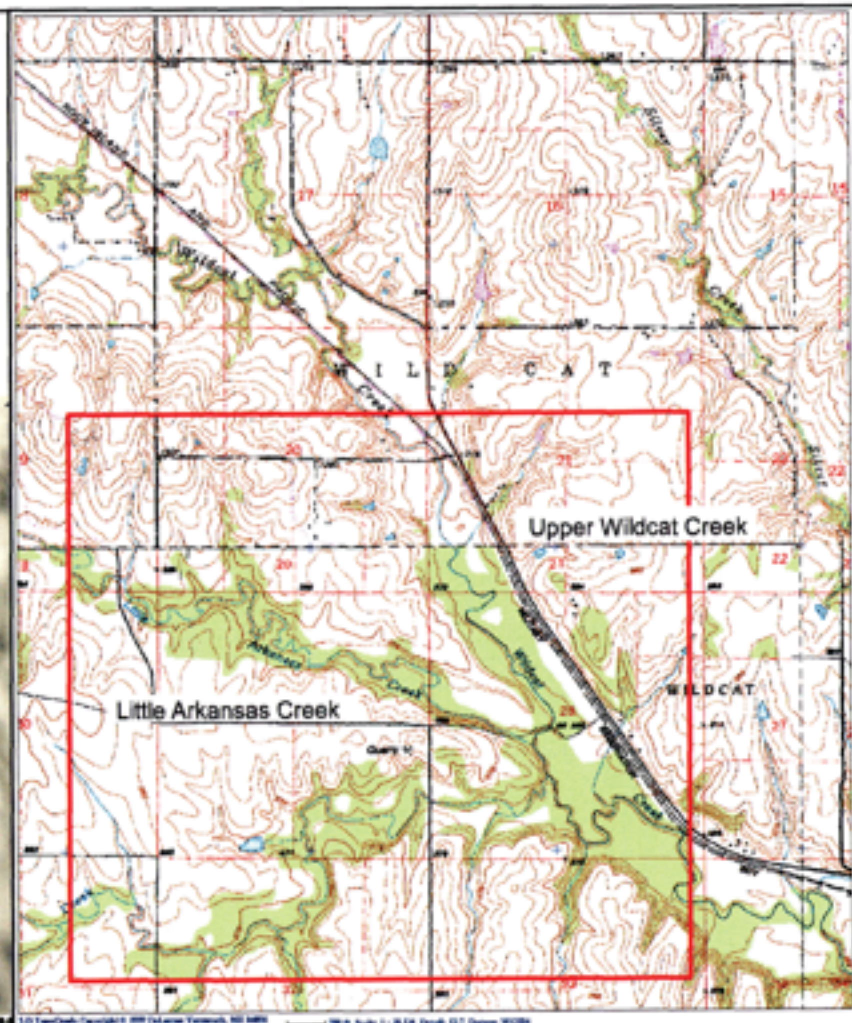
USGS Topographic Quadrangle

Figure 43

Upper Wildcat Creek and the Little Arkansas Creek



3-dimensional view (8x vertical exaggeration)



USGS Topographic Quadrangle

Figure 44

Conclusions

A model of culture period-landform associations provides a general framework within which to consider the taphonomy of prehistoric settlement, which to a large degree influences the patterns perceived. This study has dealt with the loess mantle of the uplands and the alluvial surfaces and fills of the valleys. Although much of the cultural record is lost or disturbed, some remains exposed on the surface or within the upper few centimeters, but much more of it is buried, often deeply. Through absolute age determination, stratigraphic correlation, and landform mapping, the probability of locating buried archaeological remains has been articulated in a cultural-specific fashion.

This phase of the USACERL-funded Fort Riley project represents a continuation of geoarchaeological investigations aimed at producing a high-resolution model of late-Quaternary landscape change and potentials for burial of prehistoric cultural materials. Specific tasks and activities included:

1. Continued refinement of spatial data (2-D) of landform-sediment associations in an ArcView format. Maps within this report are the representation of the relationships established between the age of sedimentary bodies and their distribution, with a perspective on distribution of prehistoric cultural remains.
2. Development of a computerized ACCESS database to assess the impact of the military tank emplacements via the “dig permit” data. This task could not be accomplished due to an inaccessibility of the hardcopy data, i.e., it was not provided by the government.
3. Preparation of three-dimensional visualizations of landform-sediment assemblages using ESRI ArcView 3-D Analyst. Surface and subsurface rendering of the valley fills were generated to depict the extent of unconsolidated sediment bodies in valleys.

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