A Statewide Geographic Information System (GIS) as a Predictive Tool for Locating Deeply Buried Archeological Deposits in Nebraska: Phase II

FINAL REPORT

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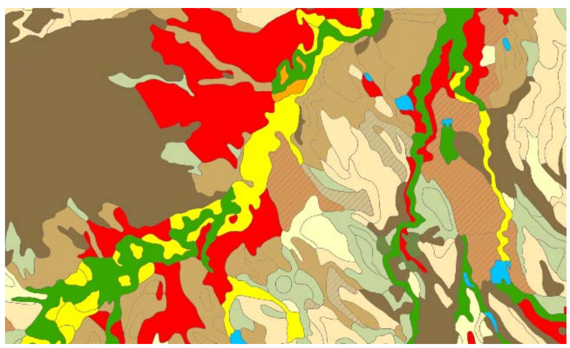

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16. Abstract
This project developed a GIS to assist with the identification of deeply buried archeological sites in alluvial settings across Nebraska with the exception of the Sandhills region. Soil survey data, previous geoarcheological investigations, landform position, and other information was used to rank the potential of any stream valley setting as low, low-moderate, moderate-high, or high potential to contain buried soils (paleosols). While the presence of buried soils does not necessarily translate to presence of buried archeological sites, the potential for such sites is far greater in paleosols. The GIS can be used by NDOT and other agencies with statutory historic preservation obligations, to identify tracts on proposed construction projects that might require deep mechanical testing (backhoe or coring) in search of buried archeological properties.

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Nebraska Department of Transportation Project SPR-P1(20) M100

"A Statewide Geographic Information System (GIS) as a Predictive Tool for Locating Deeply Buried Archeological Deposits in Nebraska: Phase II"

September 2021

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1. Introduction

1.1 Scope and Background

This project is the second phase of an effort designed to assist cultural resource specialists involved in Nebraska Department of Transportation (NDOT) and the Federal Highway Administration (FHWA) project planning and development. The goal was to develop Geographic Information System (GIS) data layers that spatially delineate different landform-sediment assemblages (LSAs) and depict the associated geologic potential for buried cultural deposits in select watersheds in Nebraska. The *Nebraska Buried Sites GIS* resource will allow planners and cultural resource specialists to determine whether future project areas are likely to be free of deeply buried sites or whether subsurface exploration is necessary. Phase II adds to the existing digital repository of all Nebraska geoarcheological information created in Phase I, completing the watersheds not covered in 2016-2018, and refining the assignment of potential for buried cultural deposits across the state.

Prior to the early 1980s, most archeologists working in Nebraska and other areas of the Midwest relied on traditional methods of surface surveys to locate prehistoric cultural deposits. Those methods, such as pedestrian surveys and shallow shovel testing, rarely detect buried cultural materials, especially in stream valleys. Bettis and Littke (1987:3) pointed out that inadequate subsurface sampling in stream valleys has led to significant gaps in the record of known prehistoric cultural resources, as well as erroneous conclusions about some aspects of regional cultural history. Many studies (e.g., Mandel, 1994, 1996, 1997, 1999, 2002, 2006a, 2009, 2010a, 2010b, 2011, 2012, 2013a, 2013b, 2014, 2015, 2016; Mandel and Bettis, 1995, 2001a, 2003) have demonstrated that stream valleys in Nebraska have extensive geomorphic surfaces that are geologically young (often post-dating 2000 yr B.P.), and that most of the existing record of prehistoric cultures is deeply buried. Hence there is a need for understanding the age and distribution of different LSAs in order to adequately evaluate the landscape for buried archeological materials.

LSAs are landforms and underlying genetically related packages of sediment and associated soils with predictable age relationships. The impetus for considering LSAs in an archeological context is the premise that the archeological record is a component of the sedimentary record; hence, physical processes that remove, modify, and bury sediments control the preservation and visibility of the record of the human past (Bettis et al., 1996). Conceptualizing the landscape in this manner provides archeologists with a range of powerful tools for locating, evaluating, and interpreting cultural resources preserved in sediments that constitute the modern landscape (Mandel, 2006a). Other factors, all described below, also must be considered in determining the potential for buried cultural deposits.

1.2 Determining the Potential for Buried Cultural Deposits

In evaluating buried site potential, it is important to consider geomorphic processes, particularly erosion, deposition, and soil development. These processes produce a complex mosaic of LSAs that are differentially but systematically preserved in the landscape, and therefore affect the distribution and detection of archeological materials. For example, LSAs representing areas of net sedimentation (e.g., stream terraces, colluvial footslopes, and alluvial fans) have thick packages of sediment that often span the Holocene. These LSAs are typically formed by pulses of sedimentation punctuated by periods of stability and soil development and are therefore more likely to contain buried cultural deposits. In contrast, LSAs such as floodplains and upland drainageways tend to have relatively thin packages of sediment and are relatively young, often post-dating Euro-American settlement in the Plains.

In this project, determining the geologic potential for buried cultural deposits involved consideration of four factors with respect to different LSAs: (1) the age of sedimentary deposits, (2) the soil stratigraphic record, (3) the depositional environment (high energy vs. low energy), and (4) the drainage conditions (poorly drained vs. well drained).

Buried cultural deposits are limited to LSAs that date to the Holocene and terminal Pleistocene. Although the time when people first arrived in mid-continental North America is uncertain, there is strong evidence of a human presence by as early as 13,500 years ago (Holliday and Mandel, 2006, 2017a). Hence, LSAs that were aggrading anytime during the past 13,500 years have potential for containing buried cultural deposits. On the other hand, LSAs that have been stable for the past 13,500 years are not likely to have *in situ* cultural materials in buried contexts. Instead, they may have cultural deposits representing Early Paleoindian through Historic period occupations on their surfaces.

The presence/absence of terminal Pleistocene and Holocene-age buried soils, especially buried A horizons, is an important factor in evaluating the potential for buried cultural deposits (Mandel, 2006a; Holliday et al., 2017). Buried soils represent previous land surfaces that were stable for a long enough period to develop recognizable soil profile characteristics (Mandel and Bettis, 2001b). If one assumes that the probability of human use of a particular landscape position was equal for each year, it follows that the surfaces that remained exposed for the longest time would represent those with the highest probability for containing cultural materials (Hoyer, 1980). In stream valleys, buried soils dating to the

Holocene and terminal Pleistocene represent those surfaces, and evidence for human occupation would most likely be associated with them.

However, prehistoric cultural deposits, even rich ones, also may be found in sediment that has not been modified by soil development (Hoyer, 1980). Hence the presence/absence of buried soils cannot be used as the sole criterion for evaluating the potentials for buried cultural materials. The mere presence of Holocene and terminal Pleistocene deposits beneath a geomorphic surface offers potential for buried cultural materials.

In the past, humans have been attracted to streams, often living on floodplains, terraces, or alluvial fans and exploiting the abundant resources available in alluvial settings. It is likely that prehistoric people were selective in choosing alluvial landforms for habitation, avoiding high-energy depositional environments, such as flood bars in zones of high-energy flooding and lateral accretion, but favoring relatively stable landforms that are elevated above the floodplain, such as terraces, alluvial fans and colluvial aprons (e.g., Mandel and Bettis, 2001b). Although alluvial landscapes are conducive to the initial accumulation of artifacts and their subsequent burial, fluvial processes may restructure the artifact patterns (Rapp and Hill, 2006: 75). For example, where sites are situated on or near the banks of stream channels, high-energy floods tend to modify cultural deposits dramatically by displacing artifacts vertically and horizontally. In some cases, stream erosion may completely remove artifacts, cultural features, and even entire sites, thereby destroying evidence of human occupation (Mandel et al., 2017). On the other hand, vertical accretion, which is a relatively low-energy process compared to lateral accretion, can result in rapid burial and preservation of cultural deposits in alluvial environments.

Drainage conditions also must be considered when assessing buried site potential. Today, wetlands, including marshes, shallow lakes, and wet basins and meadows, are common on the valley floors of streams and in dune fields, and they were present at various times over the past 13,000 years. Although people undoubtedly visited wetlands for hunting and gathering during that period, it is unlikely that they would have spent much time in such wet environments, and ephemeral camps rarely produce an abundant material record. By contrast, well-drained landforms, such as alluvial fans and colluvial aprons would have been attractive locations for long-term human occupations that tend to leave a rich archeological record (e.g., Almy, 1978; Mandel and Bettis, 2001b; Saucier, 1966).

1.3 Soil survey data and archeological research

The implementation of systematic soil surveys and soil mapping by national soil survey programs was one of the primary goals in soil-related research through much of the 20th century (Brevink et al., 2016). In the United States, the Natural Resources Conservation Service (NRCS) currently is the primary agency involved in conducting soil surveys and disseminating soil data. The NRCS Web Soil Survey provides online access to a wealth of data on landscapes and geomorphology as well as soils. Engineers, farmers, property appraisers, and others often rely on these data because they either use soil as a material or study its role in the environment (Miller, 2012). Although some scientists have used soil survey data to devise strategies for locating cultural resources (e.g., Beeton and Mandel, 2011; Bettis and Benn, 1984, Mandel, 1992, 2006b; Monger, 1995; Stafford and Creasman, 2002), these data are generally underutilized in archeology, probably because of the agricultural and land-use focus of the surveys (Holliday and Mandel, 2017b). In this study, we use data from the NRCS Soil Survey Geographic database (SSURGO) to provide information on the spatial distribution of different LSAs and to determine the associated geologic potential for buried cultural resources. Based on this information, a GIS-based model (Nebraska Buried Sites GIS) was developed to identify the potential for buried archeological material in Nebraska. The model is focused on stream valleys but also includes assessments of buried potential for uplands where relationships could be gleaned. Data from a large volume of field-based research conducted throughout the region, including soil stratigraphy, lithostratigraphy, and chronostratigraphy, were used to verify the model. A user's guide for the Nebraska Buried Sites GIS is provided with this report (see Part II).

2. Methodology

Research in the Central Great Plains involving geomorphology combined with archeology (or *geoarcheology)* has produced a large volume of data in Nebraska. However, before the present investigation, no collective repository or database of this geoarcheological information existed. Hence, Phase I of this project, conducted in 2016-2018, involved the identification and gathering of extant technical reports, journal articles, book chapters, and other publications containing pertinent geoarcheological data in and around Nebraska. A literature review was conducted that utilized existing databases of published and unpublished reports identified many relevant resources containing geomorphological information. As the primary repository for archeological literature in the state, History Nebraska provided the bulk of this information. Additional resources were identified and collected directly from geomorphologists and their institutions with a history of research in the state, such as Dr. Rolfe Mandel's work with the State Archeology Office and State Historic Preservation Office, the University of Nebraska, and Augustana College. All resources were converted to digital formats where applicable and compiled in a comprehensive bibliographic database. As stratigraphic profiles and associated data from select localities were used in verifying cultural resource potential based on soil survey data, related photographs and profiles were extracted from the referenced reports and added to the GIS as attachments. This geoarcheological repository was updated as part of Phase II of the project, including new data collected from fieldwork in the Lodgepole Creek and White River valleys of western Nebraska (Figure 1).

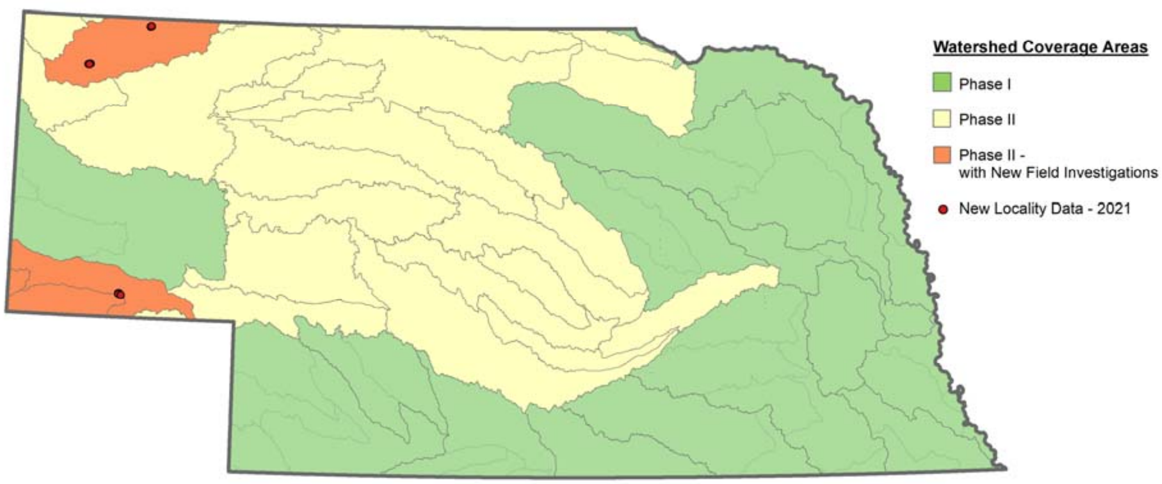

Figure 1. Map of Nebraska showing USGS HUC-8 watershed coverage by project phase.

In Phase II, GIS data files (ESRI geodatabases) were developed that spatially depict the potential for buried cultural resources by county. Determining the potential for buried cultural deposits involved consideration of four factors: (1) the age of sedimentary deposits, (2) the soil stratigraphic record, (3) the depositional environment (high energy vs. low energy), and (4) the drainage conditions (poorly drained vs. well drained). Soil data from the Soil Survey Geographic database (SSURGO) was the primary dataset used to obtain information pertaining to the four factors. Additional descriptions from the NRCS Official Soil Series Descriptions (OSD) database (https://soilseries.sc.egov.usda.gov/osdname.aspx) were also used. The four factors were assessed as follows:

1. *Age of sedimentary deposits.* Ages were estimated based on the magnitude of soil development. Age estimates were further refined based on available radiocarbon chronologies.

2. *Soil-stratigraphic record.* Soil descriptions from SSURGO and OSD databases and soil-stratigraphic information gleaned from field investigations were used to assess the potential for buried soils.
3. *Depositional environment.* Textural information (i.e., coarse grained vs. fine-grained deposits) was used to infer high energy vs. low energy environments.
4. *Drainage conditions.* Soil series in the SSURGO database are associated with seven classes of soil drainage, ranging from excessively drained to very poorly drained. Supporting information on drainage is available via SSURGO and OSD soil horizon descriptions. For example, poorly drained soils typically have gleyed horizons (i.e., Bg horizons) and redoximorphic concentrations and depletions indicate shallow, fluctuating water tables.

The following specific procedures were used to assess potential:

1. Soil data from SSURGO were obtained via the NRCS Web Soil Survey (http://websoilsurvey.sc.egov.usda.gov) for each county. Exported data included spatial data in ESRI shapefile format, associated tabular data (as text files), and Microsoft Access databases (mdb files). Each shapefile contains discrete map unit polygons that are defined in terms of their soil characteristics.

2. SSURGO tabular data was linked to the Microsoft Access database and select tables exported to Microsoft Excel for each county. The following tables were extracted in order to assess the four factors for determining buried potential as well as pertinent geomorphic information (e.g., the type of LSAs on which a given soil series occurs):

    a. Soils
        i. hzname – soil horizon name.
        ii. hzdepth – distance from the top of the soil to the upper boundary of a given soil horizon.
    b. Depositional Environment
        i. pmkind –general composition of the soil parent material.
        ii. pmgroupname – parent material modifiers (i.e., texture), kind and origin. Where texture information was not given, data from the OSD was used to determine texture.
    c. Drainage
        i. drainagecl – natural drainage conditions (7 classes) of the soil.
    d. Geomorphology

   i. geomdesc – general geomorphic setting. May include multiple features and relationships.
   ii. geomfrname – specific geomorphic features.
   iii. ecoclassname – descriptive name of a particular ecological community. Useful for subdividing floodplain units.
   iv. Localphase – criterion used locally to help identify a soil component.
   v. FloodFCl – flooding frequency. Useful for delineating geomorphic features (e.g., floodplains from terraces).
   vi. slope – average slope (in percent) of a given map unit.

Other pertinent tables extracted include:

a. compname – name (i.e., soil series) assigned to map unit based on range of properties.
b. musym – map unit symbol. 4-digit string used to identify map unit name.
c. mukey – map unit key. Used to uniquely identify a record in the map unit table.
d. cokey – component key. Used to identify a record in the component table.
e. comppct – the percentage of the component of the map unit. Used to provide a degree of confidence in the assignment for buried potential.

3. Within Excel, map units were separated into two distinct feature classes based on parent material and landscape position/modification. The first feature class labelled “potential” consists of alluvial and colluvial map units. It includes a range of LSAs, such as terraces, floodplains, alluvial fans, and colluvial footslopes. The second feature class labelled “other” consists of discrete categories of map units associated with loess, till, alluvium (in upland settings; typically, paleoterraces), and outwash parent materials. A general “uplands” category includes map units associated with residual soils, rock outcrops, and colluvium (not footslopes). The “modified” category includes soils modified by anthropogenic activity (e.g., urban soils, quarries, landfills, etc.), and finally, a “water” category includes features such as rivers, lakes, sewage ponds, etc.

4. Based on SSURGO data, a scoring system was developed for map units with soils developed in alluvium and colluvium. Scores were assigned to each map unit based on the following factors:

Flood frequency/local phase

frequent – 1
occasional – 2

- rare/none – 3
- channeled – 0

Drainage
- Very poorly drained/excessively drained – 1
- Poorly drained – 2
- Somewhat poorly drained – 3
- Moderately well drained – 4
- Well drained – 5

Geomorphology/landscape position
- Floodplain (1-3)
  - Depressions, channels, drainageways, swales, flats, wetlands – 1
  - Clayey, sandy, overflow – 2
  - Loamy, silty – 3
- Floodplain step – 4
- Terrace/footslope – 5

Soil horizonation
- Thin A horizons (A<50cm) – 1
- Gleyed horizons (Bg) – 2
- Overthickened A horizons (A>50cm) and Bw horizons – 3
- Bk horizons – 4
- Bt horizons – 5

Parent material (texture)
- Sand – 1
- Clay – 2
- Silt/loam – 3

Scores for each factor were summed to provide a measure of potential for buried cultural resources: 0-9 low potential, 10-12 low-moderate potential, 13-15 moderate-high potential, 16+ high potential.

In addition to scoring, a "variable" assignment was used for select map units associated with a range of different landscape positions (i.e., different LSAs) that have varying potential (e.g., upland drainageway vs. terrace). Therefore, for map units in the "variable" category, knowledge of geomorphic position in a given drainage system is needed to ascertain whether buried cultural deposits are more or less likely to occur.

5. Although map units in the "other" feature class were not scored, certain geomorphic descriptions suggest that potential for buried cultural resources may be present. Therefore, in addition to parent material (i.e., loess, till, etc.) and "modified" categories, a "potential" category was created in this feature class for these specific map units and notes provided pertaining to the nature of the potential. Examples include:

    a. Playas, swales, depressions. There is high potential for buried cultural resources on the margins of these features.
    b. Stream terraces mantled by loess and/or eolian deposits. The ages of the eolian deposits are typically unknown. If these deposits are Holocene in age (e.g., Bignell Loess), then there is high potential for buried cultural resources. In contrast, if the deposits are Pleistocene in age (e.g., Peoria Loess), then there is a low potential for buried cultural resources.

6. Scored excel sheets were imported into ArcMap to create geodatabases (composed of two feature classes: "potential" and "other") for each county that spatially illustrate the potential for buried cultural resources.

7. Assignments of buried potential were assessed and modified based on extant geoarchaeological information.

3. Case studies

In Phase II, the soil-based GIS model was tested in the Lodgepole Creek and White River valleys (Figure 1). Scores for each variable described in the methods section of this report were summed to provide a measure of potential for buried cultural resources: 0-9 low potential, 10-12 low-moderate potential, 13-15 moderate potential, and 16+ high potential.

3.1. Lodgepole Creek, southwestern Nebraska.

Figure 2 shows the potential for buried cultural deposits in the Lodgepole Creek valley. Based on SSURGO data, the Bankard soil series, which is located on the modern floodplain, was assigned a score of 7, indicating low potential. The low score is attributed to (1) excessive drainage conditions, (2) a floodplain setting, (3) weakly developed soils with A-C horizonation, and (4) sandy textured sediments. Overall, the SSURGO data indicate a high-energy environment proximal to the channel. It is very unlikely that any deeply buried *in situ* cultural deposits are preserved in this type of depositional environment. Information gleaned from Core LP-1, which was collected from the modern floodplain of Lodgepole Creek (Figure 2), supports this interpretation. The floodplain surface is approximately 1 m above the modern stream channel. The LP-1 core was 1.8 m long and revealed a thin, weakly expressed surface soil (Soil 1) with an A-C profile developed in an upward-fining sequence (Figure 3; Appendix 1, Table 1). The A horizon is 16 cm thick and consists of grayish brown (10YR 4/2) loam. The C horizon is stratified and consists of a 94 cm-thick deposits of sandy loam, a 55 cm-thick deposit of medium to coarse sand, and a deposit of medium to very coarse sand with fine to medium pebble gravel that is at least 15 cm thick.

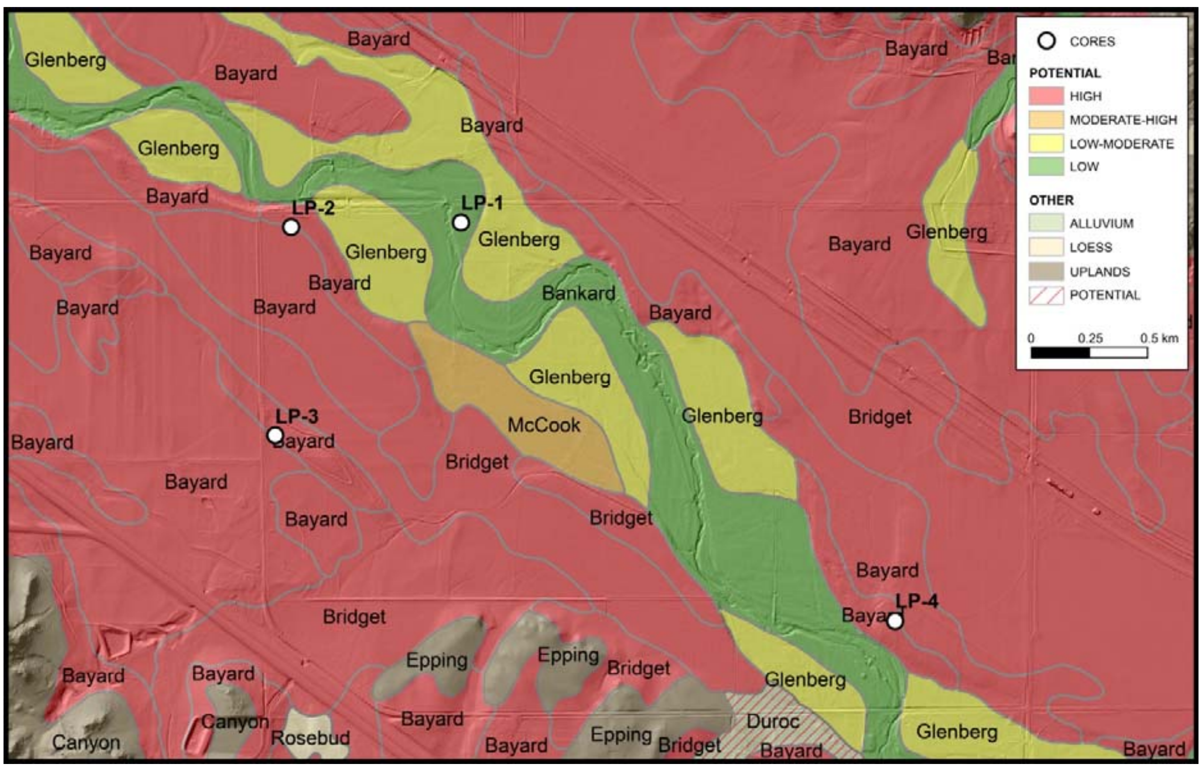

Figure 2. Map of the Lodgepole Creek valley investigated in Phase II. Map shows soils series, coring locations, and potential for buried cultural deposits.

The Glenburg and McCook soil series received low-moderate and moderate-high scores of 12 and 15, respectively. These scores were based on the (1) well-drained conditions, (2) floodplain settings, and (3) weakly developed soils with A-C horizonation. Glenburg soils have sandy textures whereas McCook soils have loamy textures; hence, McCook soils were assigned higher scores. These soil series are similar to the Bankard soil, with the exception of the drainage characteristics, flooding frequency, and, in the case of the McCook series, texture. All of these characteristics result from landscape positions more distal to the modern channel compared to the Bankard soil (Figure 2). Hence, there is a relative increase in the likelihood of buried cultural deposits in depositional setting depicted by the Glenburg and McCook soils. The characteristics of these soil series were not, however, confirmed with coring in the Lodgepole Creek study area.

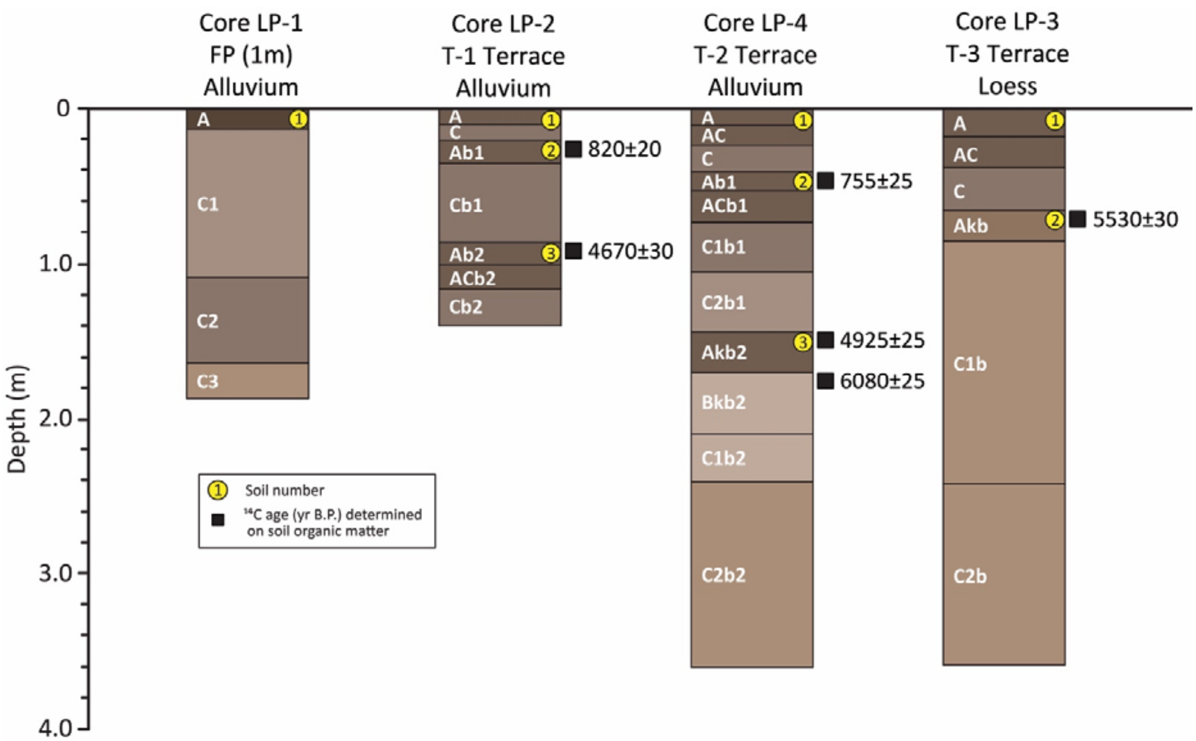

Figure 3. Diagram of the soil-stratigraphy from four cores collected in the Lodgepole Creek valley.

The Bayard soil series received a high potential score of 17. Bayard soils are primarily associated with stream terraces in the Lodgepole Creek valley. The high score results from (1) well-drained conditions, (2) stream terrace LSAs, and (3) moderately developed soils with A-Bw horizonation. Some Bayard soils have less well-developed A-C horizonation and are associated with either low stream terraces or terrace scarps. Bayard soils have sandy textures that typically indicate high-energy depositional environments. However, sediment texture in the Lodgepole Creek valley also may reflect the local sediment sources, e.g., local bedrock (Ogallala Formation) that is comprised of sandstone and gravel conglomerates. Cores LP-2, LP-3, and LP-4 were collected from a suite of terraces in Lodgepole Creek valley with the Bayard soil mapped on those geomorphic surfaces (Figures 2 and 3). All three of these cores revealed the presence of buried soils, supporting the high potential score for buried cultural resources predicted by the model.

The T-1, T-2, and T-3 terrace surfaces are approximately 3, 6, and 8 m, respectively, above the modern stream channel of Lodgepole Creek. The LP-2 core was collected from the T-1 terrace fill. The core was 1.4 m long and revealed a thin, weakly expressed surface soil (Soil 1) with an A-C profile developed in an upward-fining sequence (Figure 3; Appendix 1, Table 2). The A horizon is 10 cm thick and consists of a dark grayish brown (10YR 4/2) loam. The underlying C horizon is only 11 cm thick and consists of a sandy loam.

Soil 2 is similar to Soil 1 and has a weakly expressed A-C profile. The Ab1 horizon is 16 cm thick and consists of a dark grayish brown (10YR 4/2) loam. The Cb1 horizon is 38 cm thick and consists of a sandy loam with diffuse, fine to medium pebble gravel throughout.

Soil 3 has a weakly expressed Ak-AC-C profile. The Akb2 horizon is 15 cm thick and consists of a dark grayish brown (10YR 4/2) loam with few, very fine carbonate threads. The ACb2 horizon is only 15 cm thick and consists of a dark grayish brown (10YR 4/2) sandy loam. The Cb2 horizon is over 35 cm thick and consists of a sandy loam with fine to medium pebble gravel throughout.

The LP-4 core was collected from the T-2 terrace fill. The core was 3.6 m long and revealed a thin, weakly expressed surface soil (Soil 1) with an A-AC-C profile developed in an upward-fining sequence (Figure 3; Appendix 1, Table 3). The A horizon is 10 cm thick and consists of a dark grayish brown (10YR 4/2) loam. The underlying AC horizon is 15 cm thick and consists of a sandy loam. The C horizon is 14 cm thick and is also a sandy loam.

Soil 2 is similar to Soil 1 and has a weakly expressed A-AC-C profile. The only differences between Soil 2 and Soil 1 are that horizon thicknesses are slightly greater in Soil 2. Also, the C horizon of Soil 2 is stratified and consists of a 29 cm-thick deposit of sandy loam and a 39 cm-thick deposit of silt loam.

Soil 3 has a moderately expressed Ak-Bk-C profile. The Akb2 horizon is 27 cm thick and consists of a grayish brown (10YR 5/2) silt loam with few, very fine carbonate threads. The Bkb2 horizon is 38 cm thick and consists of a light gray (10YR 7/2) silt loam with common fine and very fine carbonate threads and few patchy carbonate coats on ped faces. The C horizon (C1b2 + C2b2) has a combined thickness of at least 152 cm thick and is stratified. The C1b2 horizon is a loam whereas the C2b2 horizon consists of medium to coarse sand with very fine to fine pebble gravel.

The LP-3 core was collected from the loess-mantled T-3 terrace. The core was 3.6 m long and revealed a thin, weakly expressed surface soil (Soil 1) with an A-AC-C profile (Figure 3; Appendix 1, Table 4). The A horizon is 20 cm thick and consists of a dark grayish brown (10YR 4/2) silt loam. The AC horizon also is 20 cm thick and consists of silt loam. The C horizon is 28 cm thick and resembles the AC horizon except for its massive structure.

Soil 2 has a weakly expressed A-AC-C profile and is similar to Soil 1 except for the presence of secondary carbonates in the A horizon of Soil 2. The Akb horizon is 18 cm thick and consists of a dark grayish brown (10YR 4/2) loam. The AC horizon is 12 cm thick and consists of a brown (10YR 5/3) silt loam. The C1b horizon is 167 cm thick and consists of a silt loam. The C2b horizon is at least 95 cm thick and consists of loam; hence, it is coarser than the C1b horizon.

Radiocarbon ages from the three terrace cores (LP-2, LP-3, and LP-4) reveal a pattern of middle to late Holocene geomorphic change in the Lodgepole Creek valley that is strikingly similar to that documented in the Republican River valley of central Nebraska by Layzell and Mandel (2020). An age of 6080±25 yr B.P. from the Bkb2 horizon of Soil 3 in core LP-4 indicates that the T-2 fill was aggrading before ca. 6500 yr B.P. but slowed soon after that time, allowing Soil 3 to form. This period of soil formation from ca. 6500-5000 yr B.P. was accompanied by incision of Lodgepole Creek, which created the T-2 terrace. Also, based on an age of 5530±30 yr B.P. from the Akb horizon of Soil 2 in core LP-3, soils were developing on the loess-mantled T-3 terrace when Soil 3 was forming in the T-2 fill. Based on an age of 4670±30 yr B.P. determined on SOM from the Ab2 horizon of Soil 3 in core LP-2, aggradation on the valley floor (T-1 fill) resumed sometime before ca. 5000 yr B.P., but briefly slowed by ca. 4750 yr B.P., allowing Soil 3 to form in the T-1 fill.

Radiocarbon ages of 4670±30 yr B.P. from Soil 3 in core LP-2 and 4925±25 yr B.P. from Soil 3 in core LP-4 indicate that the T-1 and T-2 fills both began aggrading at the same time (ca. 5000-4500 yr B.P.), resulting in the burial of these soils. Layzell and Mandel (2020) proposed that a shift in atmospheric circulation patterns, which allowed incursions of warm, moist tropical air masses into the Central Plains after ca. 5000-4000 yr B.P., resulted in greater stream discharges and episodic large floods that were of sufficient magnitude to deposit sediment on different geomorphic surfaces (T-0c and T-1) in the Republican River valley. Based on the radiocarbon chronology and soil-stratigraphy, it appears that a similar scenario occurred in the Lodgepole Creek valley. Abundant sediment deposition on the T-1 and T-2 surfaces at that time would have provided a ready sediment source for prevailing winds to rework and deposit sediment on the T-3 surface, thereby burying Soil 2. A final pulse of aggradation after ca. 800 yr B.P. resulted in the burial of Soil 2 beneath a thin veneer of sandy loam in both the T-1 and T-2 fills.

The soil-stratigraphic record and radiocarbon chronology confirms the assignment of low potential for buried cultural deposits associated with Bankard floodplain soils and high potential for Bayard terrace soils in the Lodgepole Creek valley. Specifically, there is high potential for Middle Archaic cultural deposits associated with Soil 3 in the T-2 fill (Core LP-4). Also, there is potential for Middle Archaic cultural deposits in the T-1 fill (specifically in Soil 3 of the LP-2 core) and the loess deposits mantling the T-3 terrace (specifically in Soil 2 of the LP-3 core). However, the potential is somewhat reduced in the T-1 fill and in the loess deposits mantling the T-3 terrace because the associated buried soils are weakly developed and probably represent only 100-300 years of pedogenesis. Nevertheless, buried cultural materials have been found associated with a weakly developed buried soil in the T-3 fill in the Lodgepole Creek valley at Sidney, Nebraska (Carlson et al., 1999). Specifically, archeological site (25CN55) represents a Middle Archaic burial, 1.7 m below the surface of the T-3 terrace. This location is mapped as the Bayard soil and was assigned a score of 17, indicating high potential for buried cultural materials.

3.2. White River near Fort Robinson

Figure 4 shows the potential for buried cultural deposits in the White River valley near Fort Robinson. Based on SSURGO data, map unit polygons associated with the Glenburg soil series were assigned scores of 9, 11 and 12. Glenburg soils are located on the floodplain of the White River. The floodplain consists of two different LSAs: (1) a surface (T-0b) that is ~3 m above the modern river channel, and (2) a surface (T-0a) that is ~1 m above the modern river channel. Glenburg soils located on the T-0b surface received scores of 11 and 12, indicating low-moderate potential. These scores are attributed to (1) well-drained conditions, (2) a floodplain setting, (3) weakly developed soils with A-C horizonation, and (4) stratified, sandy textured sediments. The difference between a score of 11 and 12 for these soils was based on flooding frequency, namely, occasionally flooded verses no flooding. Information gleaned from Core WR-5, which was collected from the T-0b surface (Figures 4 and 5; Appendix 2, Table 1), supports this interpretation. At this coring location, the T-0b surface is approximately 3 m above the modern stream channel. The WR-5 core was 4.45 m long and revealed the presence of three weakly developed buried soils. These soils either have A-C or A-AC-C horizonation with an A horizon thickness of about 15 cm and silt loam textures. Radiocarbon ages indicate that soils 3 and 4 date to ca. 800 yr B.P. and 1950 yr B.P., respectively. It should be noted that SSURGO data indicate that Glenburg soils have sandy textures. However, Core WR-5 indicates Glenburg soils located on the T-0b surface have silt loam textures. Coarse-grained textures typically indicate a high energy depositional environment and, therefore, Glenburg soils on the T-0b surface would score higher if the silt loam texture was considered.

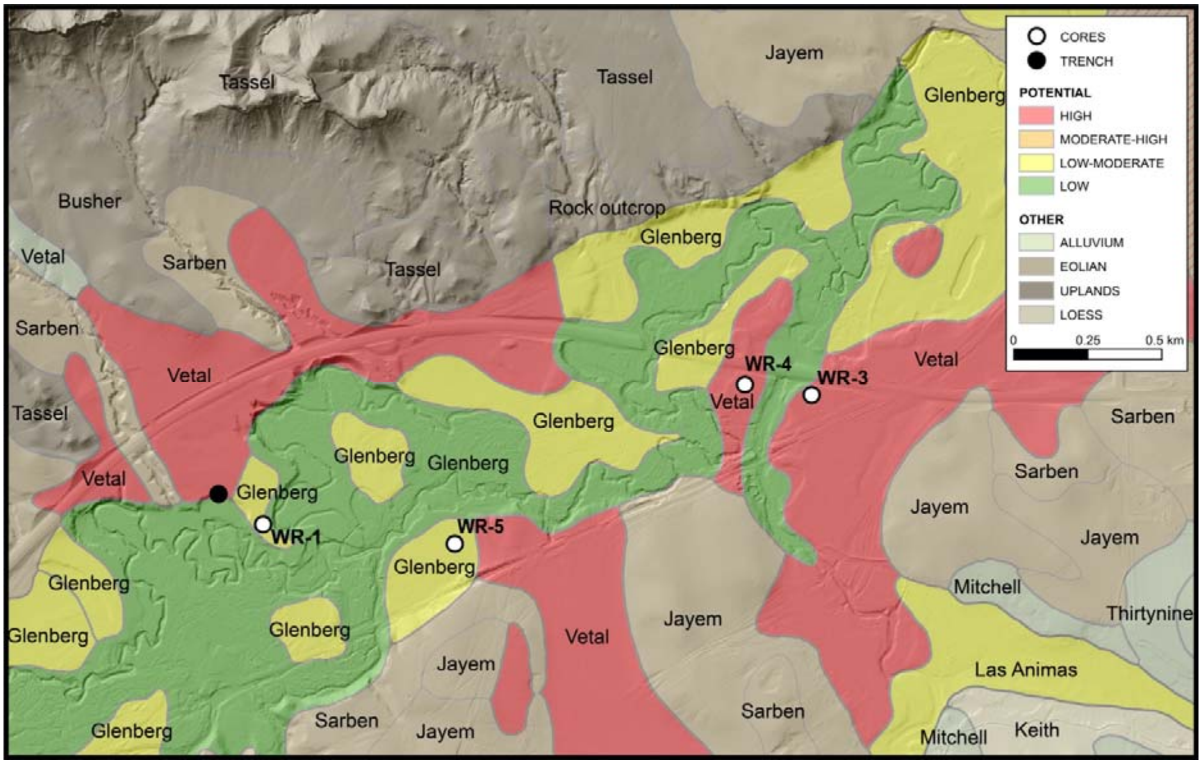

Figure 4. Map of the White River valley near Fort Robinson investigated in Phase II. Map shows soils series, coring locations, and potential for buried cultural deposits.

Glenburg soils located on the T-0a surface received a score of 9, indicating low potential for buried cultural deposits. These soils are similar to those located on the T-0b surface except for flooding frequency. The local phase descriptions for these soils note that they are channeled and frequently flooded. The characteristics of these soil series were not confirmed with coring. However, a visual inspection of a T-0a cutbank was performed and indicated that no buried soils occur in the T-0a fill.

The WR-1 core was collected from a geomorphic surface with the Glenberg series mapped on it (Figure 4). At this location, however, the surface is about 6 m above the modern stream channel and corresponds to the T-2 terrace, indicating that it was mapped incorrectly (see Section 4 for discussion of mapping limitations). Core WR-1 was 5.6 m long and revealed the presence of seven buried soils in the T-2 fill (Figure 5; Appendix 2, Table 2). Five of the buried soils (Soils 2, 4, 5, 8, and 9), as well as the surface soil (Soil 1), are weakly developed and have either A-C or A-AC-C horizonation. The A horizons of these soils consist of dark grayish brown (10YR 4/2) silt loam or loam with thicknesses ranging between 10 and 16 cm. The C horizons typically consist of silt loam, although the C horizons of soils 8 and 9 consist of very fine sand. Soils 3, 6, and 7 are more developed and have Bk horizons that consist of light brownish gray (10YR 6/2) silt loam. Bk horizon thicknesses range from 17 to 44 cm. Only Soil 3 has an intact A-Ak horizon; the A horizons of Soils 6 and 7 were stripped off by stream erosion before soil burial. Five radiocarbon samples from buried A horizons and two samples from buried Bk horizons yielded ages ranging from 4430±25 yr B.P. to 945±20 yr B.P.

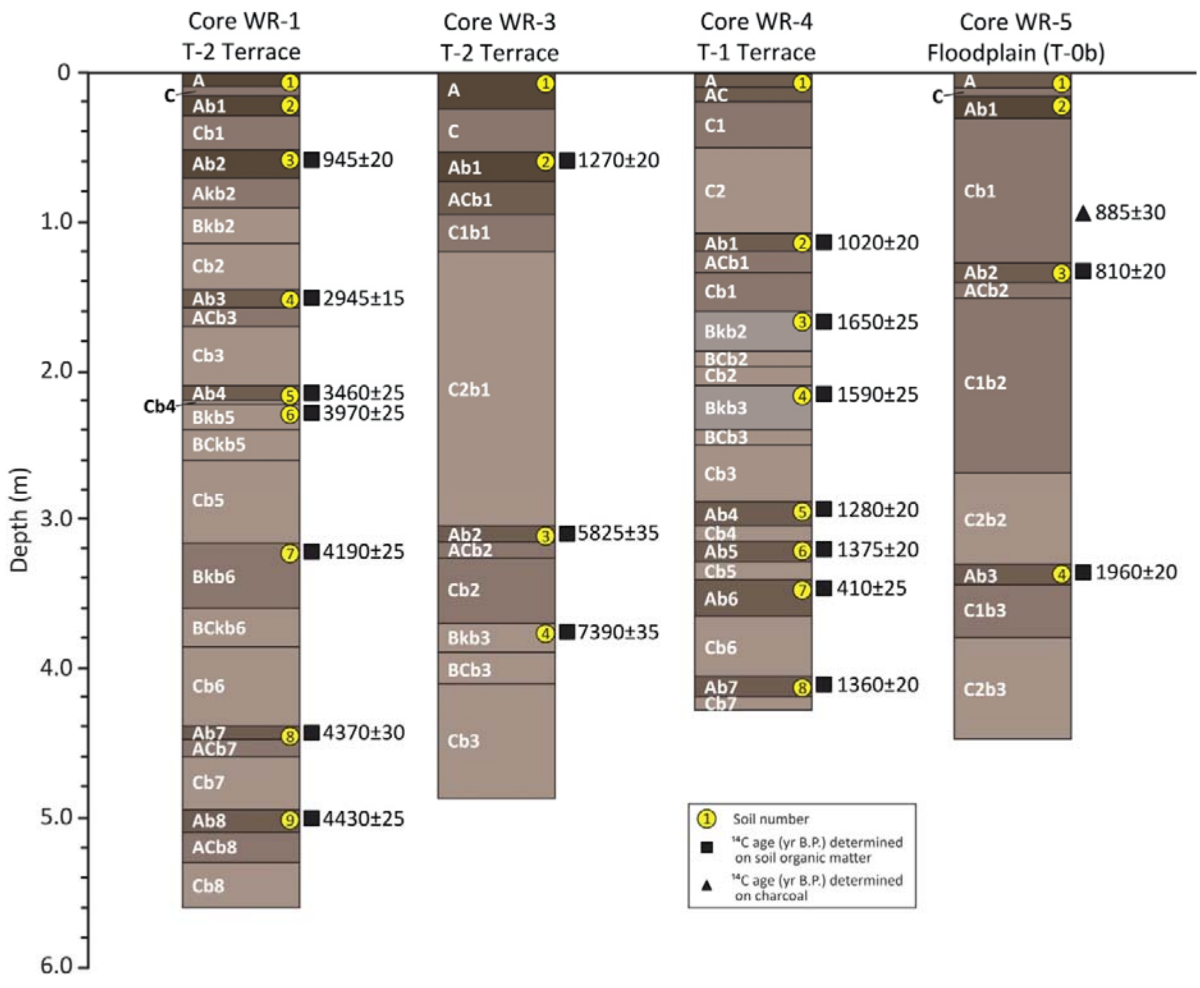

Figure 5. Diagram of the soil-stratigraphy from four cores collected in the White River valley near Fort Robinson.

The Vetal soil series received a score of 19, indicating high potential for buried cultural deposits. Vetal soils are primarily associated with stream terraces (T-2 and T-1) in the White River valley. It should be noted that some Vetal soils are mapped on hillslopes and tablelands (uplands) (Figure 4). Although these soils are formed in alluvium, they are presented as upland alluvium in the "other" feature class and not assigned a score for buried potential. The high potential score for Vetal soils on stream terraces is based on the (1) lack of flooding, (2) well-drained conditions, (3) geomorphic setting (i.e., terrace), (4) presence of cumulic A horizons, and (5) loamy textures. Cores WR-3 and WR-4 collected from the T-2 and T-1 terrace, respectively, both revealed the presence of multiple buried soils and support the high potential score assigned to Vetal soils.

Core WR-3 was collected from the T-2 terrace. The T-2 terrace is about 6 m above the modern stream channel of the White River in the study area. The core was 4.9 m long and revealed the presence of three buried soils (Figure 5; Appendix 2, Table 3). Soils 1, 2 and 3 are weakly developed with A-C or A-AC-C horizonation. The A horizons are 10 to 19 cm thick and consists of either very dark or dark grayish brown (10YR 3/2 and 4/2) silt loam. The C horizon of Soils 1 and 3 are 31 cm and 43 cm thick, respectively, and have loam textures. The C horizon (C1 + C2) of Soil 2 is much thicker and consists of a 210 cm-thick silt loam. Two radiocarbon samples from the upper 10 cm of the Ab1 and Ab2 horizons yielded ages of 1270±20 yr B.P. and 5825±35 yr B.P., respectively.

Soil 4 is well developed and has a 22-cm-thick Bk horizon that consist of a light brownish gray (10YR 6/2) silt loam. Soil 4 is truncated; the A horizon was stripped off by stream erosion before soil burial. The C horizon is coarser than the C horizons of other soils and consists of a very fine sand. A radiocarbon sample from the upper 10 cm of the Bkb3 horizon yielded an age of 7390±35 yr B.P.

Core WR-4 was collected from the T-1 terrace. The T-1 terrace is about 5 m above the modern stream channel of the White River. The core was 4.3 m long and revealed the presence of seven buried soils (Figure 5; Appendix 1, Table 4). Soils 1, 2, 5, 6, 7 and 8 are weakly developed with A-C or A-AC-C profiles developed in upward fining sequences. The A horizons are 10 to 23 cm thick and consist of dark grayish brown (10YR 4/2) silt loam. The C horizons of these soils typically have loam to very fine sand textures and vary in thickness from 11 cm (Soil 5) to 87 cm (Soil 1; C1 + C2).

Soils 3 and 4 exhibit greater magnitudes of soil development. Specifically, they have approximately 20 cm-thick Bk horizons that consist of gray (10YR 6/1) silt loam. Secondary carbonate morphology consists of few, very fine carbonate threads and, in the case of Soil 3, few patchy carbonate films on ped faces. Both soils are truncated; the A horizons were stripped off by stream erosion before soil burial. Five radiocarbon samples from buried A horizons and two samples from buried Bk horizons yielded ages ranging from 1650±25 yr B.P.

to 410±25 yr B.P. However, there are a number of inverted ages in the sequence. The young 410±25 yr B.P. age from Soil 7 was likely contaminated by younger carbon, potentially from roots. The ages determined on SOM from the Bk horizons of Soils 3 and 4 (1650±25 and 1590±25, respectively) are older than the ages determined on SOM below them. Radiocarbon ages determined on SOM from B horizons tend to be more strongly influenced by older detrital organic carbon compared to ages determined on SOM from A horizons (Mandel et al. 2018), which probably accounts for the stratigraphically inverted ages in Core WR-4. Despite these complications, the radiocarbon chronology indicates that the age of the T-1 fill is younger than ca. 1400 yr B.P.

During field investigations, it was observed that Vetal soils also occur on alluvial fans that grade to the T-2 terrace. Those fans are not documented in the SSURGO database, thus highlighting issues related to the spatial scale of soil survey mapping (see Section 4). Coring was attempted on a fan surface (Core WR-2) that graded to the T-2 surface near core WR-1. However, there was refusal at approximately 1.5 m below surface. Hence, a trench was excavated with a backhoe to investigate the soil-stratigraphy of the fan (Figure 4). Three buried soils at depths of 370, 428, and 456 cm beneath the fan surface were observed. The buried soils had A-C horizonation with silt loam textures. Radiocarbon samples from the upper 10 cm of the buried A horizons yielded radiocarbon ages of 2750±25, 3170±20, and 3250±25 yr B.P., respectively.

The soil stratigraphy and radiocarbon chronology of the White River valley indicate a very dynamic system with multiple periods of alluviation, landscape stability, and erosion throughout the Holocene. For example, ages of ca. 7400 and 5800 from the WR-3 core indicate that the T-2 fill was aggrading during the early Holocene but was punctuated at those times by periods of landscape stability. The younger ages at similar depths (~ 3-5 m) in the WR-1 core indicate that this is likely a slightly younger inset fill. Furthermore, the large package of unmodified, relatively homogenous C horizon material from about 1 to 3 m below surface in Core WR-3 implies deposition during a large flood event, which likely eroded and removed some of the older T-2 fill. The age of ca. 1950 yr B.P at the bottom of Core WR-5 is older than the ages in the T-1 fill (Core WR-4), implying that this is an older fill into which the T-0b fill is inset. The dynamic nature of the White River has important implications for the preservation of buried cultural resources.

Overall, the soil-stratigraphic record and radiocarbon chronology confirms the assignment of high potential for buried cultural deposits associated with Vetal stream terrace soils and low-moderate potential for Glenburg soils on the T-0b surface in the White River valley. Specifically, there is high potential for Early to Late Archaic cultural deposits associated with buried soils deeper than 1 m in the T-2 fill. There also is potential for Late Archaic cultural materials in alluvial fans that grade to the T-2 surface. Finally, there is potential for Middle to Late Woodland cultural deposits in the upper 1 m of the T-2 fill (specifically in Soil 3 of the WR-1 core and Soil 2 of the WR-3 core), and in the T-1 fill. Late Archaic and younger cultural deposits may occur in buried contexts in the T-0b fill. However, the potential is somewhat reduced in the majority of buried soils in the valley fills because most of those soils are weakly developed and probably represent only 100-300 years of pedogenesis. Nevertheless, buried cultural deposits have been found associated with a weakly developed buried soil in the T-2 fill in the White River valley near Crawford, Nebraska (Bozell et al., 1988). Specifically, investigations at the Slaughterhouse Creek site (25DW17) revealed the presence of four hearths and one concentration of ceramics associated with a soil buried approximately 60 cm below the surface of a terrace. Based on the field investigations conducted as part of Phase II, this terrace is likely the T-2 and the buried soil containing cultural materials likely correlates with Soil 2 of the WR-3 core.

3.3. White River at Slim Butte Road

Figure 6 shows the potential for buried cultural deposits in the White River valley at Slim Butte Road. The Munjor, Glenberg, and Haverson soil series are located on the floodplain of the White River at that locality. Also, some Haverson soils occur on stream terraces (see later discussion). Based on SSURGO data, these floodplain soils were assigned scores of 10, 12, and 13, respectively. The floodplain consists of two different LSAs: (1) a surface (T-0b) that is ~3 m above the modern river channel, and (2) a surface (T-0a) that is ~1 m above the modern river channel. Glenburg and Haverson soils located on the T-0b surface received scores of 12 and 13, indicating low-moderate and moderate-high potential for buried cultural deposits, respectively. These scores are attributed to the (1) well-drained conditions, (2) floodplain setting, and (3) weakly developed soils with A-C horizonation. Haverson soils differ from Glenburg soils in that they are occasionally flooded and consist of loamy rather than sandy textures.

Information gleaned from Core SB-2, which was collected from the T-0b surface (Figures 6 and 7), supports the moderate-high score assigned to the Haverson soil. At that location, the T-0b surface is approximately 3.5 m above the modern stream channel. Core SB-2 was 3.3 m long and revealed a thin, weakly expressed surface soil (Soil 1) with an A-C profile (Figure 7; Appendix 3, Table 1). The A horizon is 10 cm thick and consists of a dark grayish brown (10YR 4/2) silt loam. The underlying C horizon is 119 cm thick and is stratified, consisting of 3-10 cm-thick beds of silty clay, clay, and silt loam. A charcoal sample from the C horizon yielded a radiocarbon age of 75±20 yr B.P., indicating that the upper ~1 m of sediment was deposited within the last 100 years.

Soil 2 has a weakly expressed Ak-C profile. The Akb horizon is 21 cm thick and consists of a dark grayish brown (10YR 4/2) silty clay loam. The C horizon is stratified; the C1b horizon consists of a 58 cm-thick deposit of silty clay, and the C2b horizon consists of a deposit of clay loam that is at least 122 cm thick, interbedded with thin beds of very fine sand. A radiocarbon sample from the upper 10 cm of the Akb horizon yielded an age of 2155±25 yr B.P.

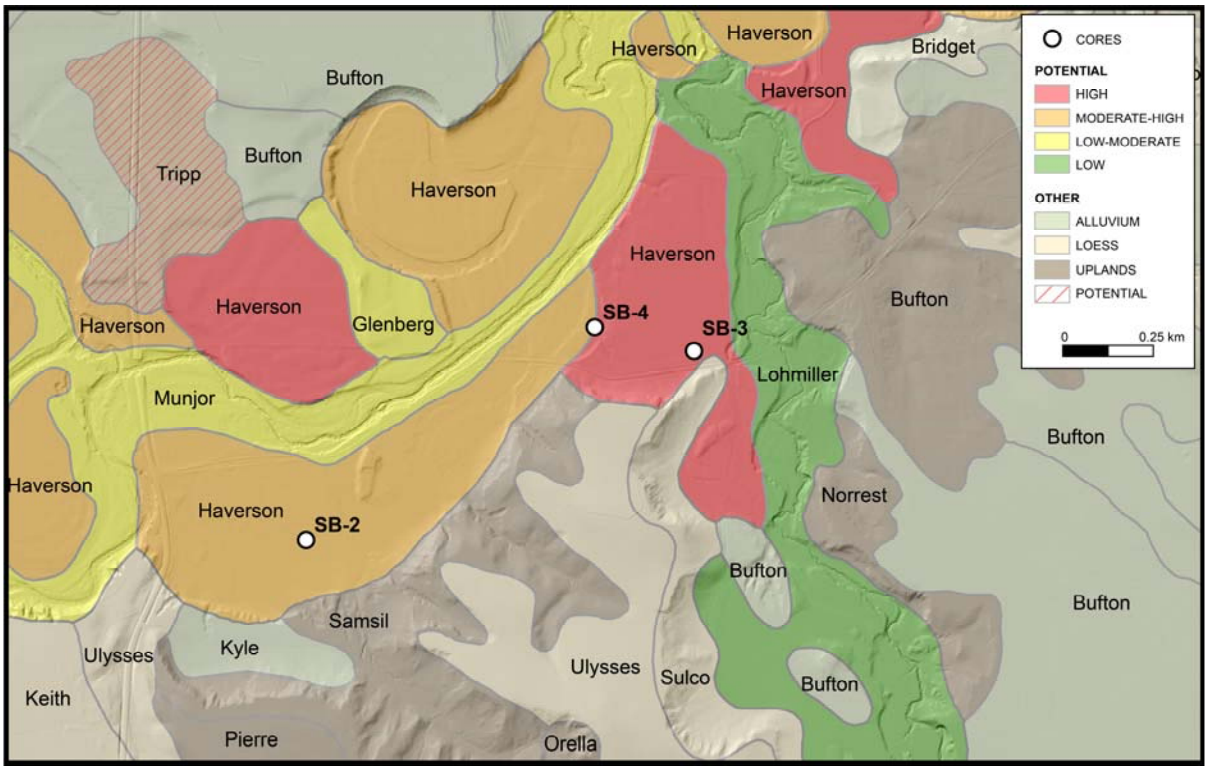

Figure 6. Map of the White River valley near Slim Butte Rd investigated in Phase II. Map shows soils series, coring locations, and potential for buried cultural deposits.

Core SB-4 also was collected from a location mapped as the Haverson floodplain soil (Figure 6). However, at that location the geomorphic surface was about 5 m above the modern stream channel and was designated as the T-1 terrace. The SB-4 core was 4.8 m long and revealed a thin, weakly expressed surface soil (Soil 1) with an A-C profile (Figure 7; Appendix 3, Table 2). The A horizon is 10 cm thick and consists of a dark grayish brown (10YR 4/2) silt loam. The underlying C horizon is 18 cm thick and also is a silt loam.

Soil 2 has a weakly expressed A-AC-C profile developed in an upward-fining sequence. The Ab horizon is 10 cm thick and consists of a dark grayish brown (10YR 4/2) silt loam. The C horizon is stratified; the C1b horizon consists of a 140-cm-thick bed of silt loam, the C2b horizon consists of a 190 cm-thick bed of sandy loam, and the C2b horizon consists of a bed of medium to very coarse sand that is over 100 cm thick. Based on the soil-stratigraphy of the SB-4 core, there is little potential for buried cultural deposits associated with the T-1 fill despite being mapped as an area with moderate-high potential. This finding highlights issues related to both the spatial scale of soil surveys as well as the internal variability inherent in alluvial deposits (see Section 4).

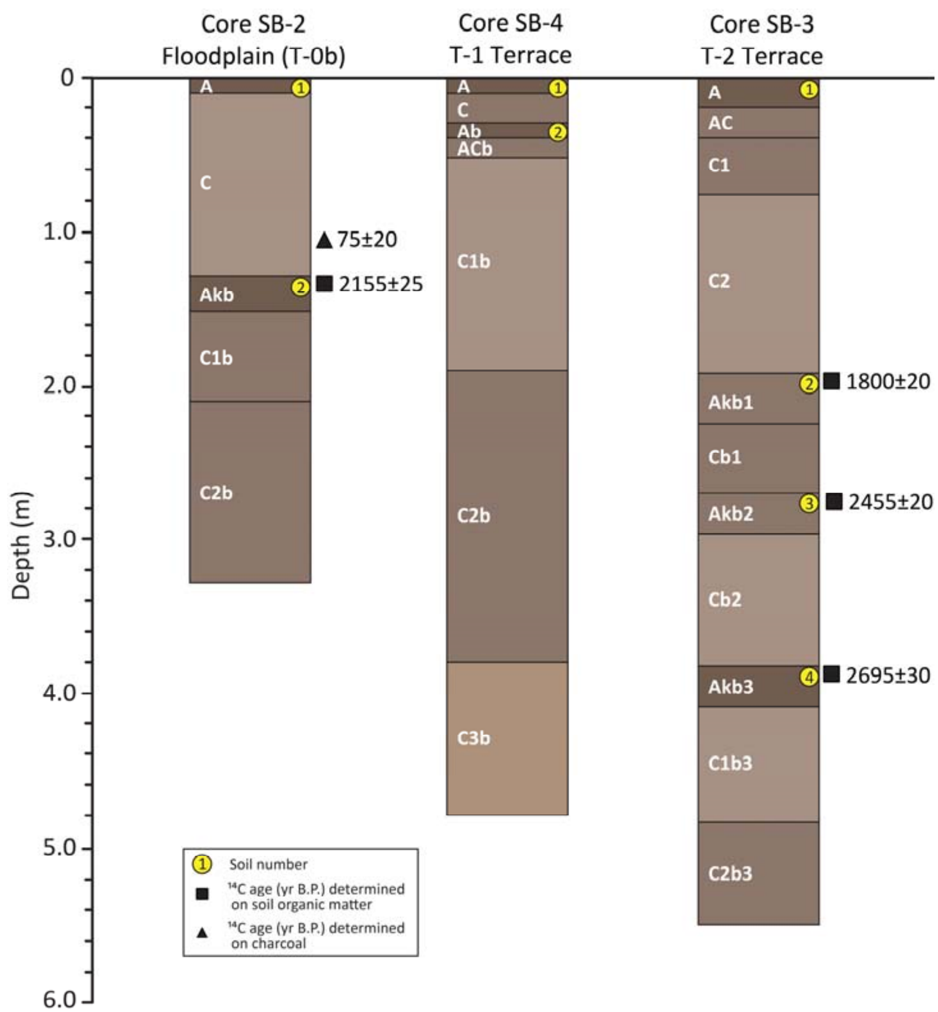

Figure 7. Diagram of the soil-stratigraphy from three cores collected in the White River valley at Slim Butte Road.

Munjor soils located on the T-0a surface received a score of 10, indicating low-moderate potential for buried cultural deposits. These scores are attributed to the (1) frequent flood frequency, (2) well-drained conditions, (3) floodplain setting, (4) weakly developed soils with A-C horizonation, and (5) loamy textures. Also, the local phase descriptions for these soils note that they are channeled. The characteristics of Munjor soils were not confirmed with coring. However, a visual inspection of a T-0a cutbank was performed. This inspection identified the presence of a weakly developed soil with A-C horizonation. The profile was similar to Soil 1 in the SB-2 core in that the C horizon was over 1 m thick and stratified.

Lohmiller soils are similar to Munjor soils but have finer-grained textures and are described in SSURGO as being located in upland settings. In the field area, Lohmiller soils were assigned a score of 9 and are located in tributaries of the White River. The characteristics of Lohmiller soils were not investigated in the field.

Haverson soils also are associated with stream terraces in the White River valley and received a score of 17, indicating a high potential for buried cultural deposits (Figure 6). These soils received a higher score than Haverson floodplain soils because of their geomorphic setting (i.e, stream terraces) and lower flood frequency.

Information gleaned from Core SB-3, which was collected from the T-2 fill (Figures 6 and 7; Appendix 3, Table 3), supports the high score assigned to the Haverson soil. At this coring location, the T-2 surface is approximately 7 m above the modern stream channel. The core was 5.5 m long and revealed a thin, weakly expressed surface soil (Soil 1) with an A-AC-C profile (Figure 3; Appendix 1, Table 3). The A horizon is 20 cm thick and consists of a dark grayish brown (10YR 4/2) silt loam. The C horizon (C1 + C2) is 152 cm thick and also is a silt loam.

Soils 2, 3 and 4 all have weakly expressed Ak-C profiles. The Ak horizons of these soils consist of either dark grayish brown (10YR 4/2) or grayish brown (10YR 5/2) silt loam with thicknesses ranging between 17 and 32 cm. The C horizons consist of silt loam, except for the C2b3 horizon of Soil 4 which consists of sandy loam. Soil organic matter from the upper 10 cm of the Ak horizons of soils 2, 3, and 4 yielded radiocarbon ages of 1800±20 yr B.P., 2455±20 yr B.P., and 2695±30 yr B.P., respectively.

The soil-stratigraphic record and radiocarbon chronology confirms the assignment of moderate-high potential for buried cultural deposits associated with Haverson floodplain soils and high potential for Haverson terrace soils in this study area. Specifically, there is high potential for Early Woodland cultural deposits associated with Soils 3 and 4 in the T-2 fill.

Also, there is potential for Middle Woodland cultural deposits in the T-0b fill (specifically in Soil 2 of core SB-2) and the upper 2.5 m of the T-2 fill (specifically in Soil 2 of core SB-3). However, the potential is somewhat reduced because the buried soils are weakly developed and probably represent only 100-300 years of pedogenesis.

4. Summary of strengths and limitations

One of the main strengths of the approach taken in this study is the ability to readily identify LSAs from SSURGO data. Specifically, certain SSURGO tables include descriptions of where particular soil series occur in the landscape, e.g., floodplains, alluvial fans, terraces, upland drainageways, colluvial footslopes, etc. This information is valuable because geoarcheological studies have shown that specific LSAs are more likely to contain buried soils and therefore buried cultural deposits than others.

Another major strength of this study is the development of an objective scoring system based on select variables from SSURGO data. As new ground truth data are collected, the scoring system can easily be modified to better reflect field data and therefore better predict the potential for buried cultural deposits throughout Nebraska. In general, field investigations conducted in Phase II confirmed the scores assigned to select soil series and therefore the potential for buried cultural deposits depicted by the model.

The presence/absence of Holocene-age and terminal Pleistocene buried soils is an important factor in evaluating the potential for buried cultural deposits. One of the major limitations of SSURGO data, however, is that only the upper 1-2 m of soil parent materials are considered. Buried soils in alluvial settings in Nebraska often occur at greater depths and, therefore, key information pertaining the presence/absence of buried soils is missing. Information on types of deposits below ~2 m is important because of the nature of the alluvial stratigraphic record. For instance, unconformable stratigraphic relationships are often present in alluvial deposits and therefore the age of sediments at depth may be significantly greater than at the surface (Mandel, 2008).

A second major limitation is the spatial scale of the soil survey mapping. The prioritization of different landscape features and soil types is inherently different at different spatial scales (Hudson and Culver, 1994; Miller and Schaetzl, 2015). The SSURGO database contains information collected at scales ranging from 1:12,000 to 1:63,360. These scales permit a minimum size for delineating map units of 0.57 ha to 16.2 ha (Soil Survey Division Staff, 1993).

Consequently, the scale of most map units as well as the variability inherent in those mapping units is greater than the scale of many archeological sites (Holliday and Mandel, 2017b). Also, the discrete borders of map units may not denote actual soil boundaries because soils do not have sharp contacts and typically grade from one type into another (Holliday and Mandel, 2017b). Finally, many mapping decisions are subjective because soil survey mappers are called upon to make judgment calls based on whether a particular soil can be mapped consistently and whether it meets the objectives of the survey. For example, having too many map unit delineations may in some cases reduce the overall usefulness of a soil map. Therefore, the degree to which soil survey data accurately depicts soil-geomorphic relationships will vary depending on the training and experience of the soil mapper. Comparing soil maps across county and state boundaries can reveal the effects of this subjectivity (e.g., Sorenson et al., 1987). Also, although mappers attempt to map soil types consistently, the maps often suffer from a lack of rigorous testing to assess their accuracy (Brevink et al., 2016). In sum, the fundamental issue of scale in soil survey mapping is that the actual soils associated with a given map unit may not necessarily be those indicated on the map, even in the best-case scenario where a map unit represents a consociation. Hence, the potential for buried cultural resources in a given map unit may not be accurate.

The limitations of the soil survey data described above have hindered their use in archeological surveys. In this study, we attempted to overcome some of those limitations by groundtruthing the assignments of potential for buried cultural deposits that are based on soil survey data. Specifically, information gleaned from detailed geomorphic and geoarcheological studies were incorporated in the assessment of buried-site potential. Although previous studies are an invaluable resource, their spatial extent is restricted; hence more groundtruthing would continue to improve the predictive power of the GIS resource presented here.

This project has shown that specific soil series are associated with particular LSAs throughout Nebraska. Furthermore, field investigations have provided ground truth data for the GIS-based model and typically confirm the scores assigned to soil series and therefore the potential for buried cultural deposits. Overall, the developed GIS data layers, together with the associated detailed repository of geoarcheological information, can be used as a helpful screening tool to determine whether certain areas are likely to be free of deeply buried cultural deposits or whether subsurface exploration is necessary. Because soil survey data are generalized, they should only be used to establish first approximations of buried-site potential. Detailed field investigations are necessary to confirm and elaborate on those approximations and to establish more appropriate spatial and temporal scales.

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APPENDIX 1. Core descriptions from the Lodgepole Creek valley

Table 1. Description of Core LP-1.

Landform: Floodplain
Slope: 1%
Parent material: Alluvium

Depth (cm)	Soil Horizon	Description
		Soil 1
0-16	A	Grayish brown (10YR 4/2) loam, dark grayish brown (10YR 3/2) moist; weak fine and very fine granular structure; very friable; common fine and many very fine roots; common fine and many very fine pores; clear boundary. Contains 1-2cm lenses of fine to medium pebble gravel at 67cm and 98cm depth. Contains isolated coarse pebble gravel and fine cobble gravel at 31cm and 80cm depth.
16-110	C1	Light grayish brown (10YR 6/2) sandy loam, grayish brown (10YR 5/2) moist; massive parting to single grain; friable; few very fine roots; few very fine pores; abrupt boundary.
110-165	C2	Grayish brown (10YR 5/2) medium to coarse sand, dark grayish brown (10YR 4/2) moist; single grain; abrupt boundary.
165-180+	C3	Pale brown (10YR 6/3) medium to very coarse sand and very fine to medium pebble gravel, brown (10YR 5/3) moist; single grain.

Table 2. Description of Core LP-2.

Landform: T-1 Terrace
Slope: 1%
Parent material: Alluvium
Remarks: Soil organic matter from the upper 10 cm of the Ab1 and Ab2 horizons yielded AMS radiocarbon ages of 820±20 and 4670±30 yr B.P., respectively.

Depth (cm)	Soil Horizon	Description
		Soil 1
0-10	A	Dark grayish brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2) moist; moderate medium and fine granular; very friable; many fine and very fine roots; clear boundary.
10-21	C	Grayish brown (10YR 5/2) sandy loam, dark grayish brown (10YR 4/2) moist; massive; friable; many fine and very fine roots; many very fine pores; abrupt boundary.
		Soil 2
21-37	Ab1	Dark grayish brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2) moist; weak medium and fine subangular blocky structure parting to moderate medium and fine granular; friable; many fine and very fine roots; many very fine pores; clear boundary.
37-85	Cb1	Grayish brown (10YR 5/2) sandy loam, dark grayish brown (10YR 4/2) moist; massive; friable; few very fine roots; common very fine pores; abrupt boundary. Contains fine to medium pebble gravel throughout (~15%).
		Soil 3
85-100	Akb2	Dark grayish brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2) moist; moderate medium and fine subangular blocky structure parting to moderate medium and fine granular; friable; few very fine carbonate threads; common very fine roots; many very fine pores; clear boundary.
100-115	ACb2	Dark grayish brown (10YR 4/2) sandy loam, very dark grayish brown (10YR 3/2) moist; weak medium and fine granular structure; very friable; abrupt boundary.
115-140+	Cb2	Grayish brown (10YR 5/2) sandy loam, dark grayish brown (10YR 4/2) moist; massive; very friable. Contains fine to medium pebble gravel throughout (~30%).

Table 3. Description of Core LP-4.

Landform: T-2 Terrace
Slope: 1%
Parent material: Alluvium
Remarks: Soil organic matter from the upper 10 cm of the Ab1, Ab2, and Bkb2 horizons yielded AMS radiocarbon ages of 755±25, 4925±25 and 6080±25 yr B.P., respectively.

Depth (cm)	Soil Horizon	Description
		Soil 1
0-10	A	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to moderate fine granular structure; very friable; many fine and very fine roots; many fine pores; clear boundary.
10-25	AC	Grayish brown (10YR 4/2) sandy loam, dark grayish brown (10YR 3/2) moist; weak fine granular structure; very friable; many fine and many very fine roots; many very fine pores; clear boundary.
25-39	C	Grayish brown (10YR 5/2) sandy loam, dark grayish brown (10YR 4/2) moist; massive; very friable; many fine and very fine roots; common fine and very fine pores; abrupt boundary.
		Soil 2
39-55	Ab1	Dark grayish brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2) moist; moderate fine subangular blocky structure parting to moderate fine granular structure; very friable; few very fine roots; common fine and many fine pores; clear boundary.
55-75	ACb1	Grayish brown (10YR 4/2) sandy loam, dark grayish brown (10YR 3/2) moist; weak fine granular structure; very friable; common very fine roots; many very fine pores; clear boundary.
75-104	C1b1	Grayish brown (10YR 5/2) sandy loam, dark grayish brown (10YR 4/2) moist; massive; very friable; few very fine roots; many very fine pores; abrupt boundary.
104-143	C2b1	Light brownish gray (10YR 6/2) silt loam, grayish brown (10YR 5/2) moist; massive; friable; few very fine roots; many very fine pores; abrupt boundary.
		Soil 3
143-170	Akb2	Grayish brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2)

		moist; moderate medium and fine subangular blocky structure parting to moderate medium granular; friable; few, very fine carbonate threads; few very fine roots; common fine and many very fine pores; clear boundary.
170-208	Bkb2	Light gray (10YR 7/2) silt loam, light brownish gray (10YR 6/2) moist; moderate medium prismatic structure parting to moderate medium subangular blocky; hard; common fine and very fine carbonate threads, few patchy carbonate coats on ped faces; many very fine pores; clear boundary.
208-240	C1b2	Light gray (10YR 7/2) loam, light brownish gray (10YR 6/2) moist; massive; friable; many very fine pores; abrupt boundary.
240-360+	C2b2	Pale brown (10YR 6/3) medium to coarse sand and very fine to fine pebble gravel, brown (10YR 5/3) moist; single grain.

Table 4. Description of Core LP-3.

Landform: T-3 Terrace
Slope: 1%
Parent material: Loess
Remarks: Soil organic matter from the upper 10 cm of the Akb horizon yielded an AMS radiocarbon age of 5530±30 yr B.P.

Depth (cm)	Soil Horizon	Description
		Soil 1
0-20	A	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to moderate and fine granular; friable; many fine and very fine roots; many very fine pores; clear boundary.
20-40	AC	Grayish brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2) moist; moderate fine granular structure; very friable; many fine and very fine roots; many fine and very fine pores; gradual boundary.
40-68	C	Grayish brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2) moist; massive; very friable; common fine and many very fine roots; many very fine pores; clear boundary.
		Soil 2
68-86	Akb	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; moderate medium subangular blocky structure parting to moderate medium and fine granular; friable; few, very fine carbonate threads; common fine and many very fine roots; many very fine pores; clear boundary.
86-98	ACb	Brown (10YR 5/3) silt loam, brown (10YR 4/3) moist; weak fine subangular blocky structure parting to moderate fine granular structure; friable; common very fine roots; many very fine pores; clear boundary.
98-265	C1b	Pale brown (10YR 6/3) silt loam, brown (10YR 5/3) moist; massive; very friable; common fine and many very fine pores; clear boundary.
265-360+	C2b	Pale brown (10YR 6/3) loam, brown (10YR 5/3) moist; massive; very friable; many very fine pores. Contains 1-2cm beds of fine to medium sand at 295cm, 310cm and 330cm.

APPENDIX 2. Core descriptions from the White River valley near Fort Robinson

Table 1. Description of Core WR-5.

Landform: Floodplain (T-0b)
Slope: 1%
Parent material: Alluvium
Remarks: Charcoal from the Cb1 horizon at a depth of 87 cm yielded an AMS radiocarbon age of 885±30. Soil organic matter from the upper 10 cm of the Ab2 and Ab3 horizons yielded AMS radiocarbon ages of 810±20 and 1960±20, respectively.

Depth (cm)	Soil Horizon	Description
		Soil 1
0-10	A	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine and very fine granular structure; very friable; many fine and very fine roots; clear boundary.
10-15	C	Grayish brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2) moist; massive; very friable; many fine and very fine roots; common fine and very fine pores; abrupt boundary.
		Soil 2
15-30	Ab1	Very dark grayish brown (10YR 3/2) silt loam, very dark brown (10YR 2/2) moist; weak fine subangular blocky structure parting to moderate fine granular; very friable; many fine and very fine roots; common fine and many very fine pores; clear boundary.
30-126	Cb1	Grayish brown (10YR 5/2) loam, dark grayish brown (10YR 4/2) moist; massive; very friable; common fine and very fine roots; many very fine pores; abrupt boundary.
		Soil 3
126-140	Ab2	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to moderate medium and fine granular; friable; common very fine roots; common fine and many very fine pores; clear boundary.
140-150	ACb2	Grayish brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2) moist; weak medium granular structure; very friable; common fine and many very fine roots; common fine and many very fine pores; clear boundary.
150-270	C1b2	Grayish brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2)

		moist; massive; very friable; common very fine pores; abrupt boundary.
270-331	C2b2	Light brownish gray (10YR 6/2) loamy very fine sand, grayish brown (10YR 5/2) moist; massive; very friable; common very fine pores, abrupt boundary.
		Soil 4
331-346	Ab3	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; moderate medium and fine granular; very friable; many very fine pores; clear boundary.
346-380	C1b3	Grayish brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2) moist; massive; very friable; few very fine pores; clear boundary.
380-445+	C2b3	Light brownish gray (10YR 6/2) loamy very fine to medium sand, grayish brown (10YR 5/2) moist; massive parting to single grain; very friable.

Table 2. Description of Core WR-1.

Landform: T-2 Terrace
Slope: 1%
Parent material: Alluvium
Remarks: Soil organic matter from the upper 10 cm of the Ab2, Ab3, Ab4, Bkb5, Bkb6, Ab7, and Ab8 horizons yielded AMS radiocarbon ages of 945±20, 2945±15, 3460±25, 3970±25, 4190±25, 4370±30, and 4430±25 respectively.

Depth (cm)	Soil Horizon	Description
		Soil 1
0-10	A	Very dark grayish brown (10YR 3/2) silt loam, very dark brown (10YR 2/2) moist; weak fine and very fine granular structure; very friable; common fine and many very fine roots; clear boundary.
10-16	C	Grayish brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2) moist; massive; firm; many fine and very fine roots; common fine and very fine pores; abrupt boundary.
		Soil 2
16-30	Ab1	Very dark grayish brown (10YR 3/2) silt loam, very dark brown (10YR 2/2) moist; weak fine subangular blocky structure parting to moderate medium and fine granular; very friable; many fine and very fine roots; common fine and many very fine pores; clear boundary.
30-53	Cb1	Grayish brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2) moist; massive; very friable; common fine and many very fine roots; common fine and many very fine pores; abrupt boundary.
		Soil 3
53-75	Ab2	Very dark grayish brown (10YR 3/2) silt loam, very dark brown (10YR 2/2) moist; weak fine subangular blocky structure parting to moderate medium and fine granular; very friable; common fine and very fine roots; common fine and many very fine pores; gradual boundary.
75-92	Akb2	Grayish brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2) moist; moderate fine subangular blocky structure parting to moderate medium and fine granular; friable; few very fine carbonate threads; common fine and very fine roots; common fine and many very fine pores; clear boundary.

92-115	Bkb2	Light brownish gray (10YR 6/2) silt loam, grayish brown (10YR 5/2) moist; weak fine prismatic structure parting to moderate fine subangular blocky; friable; few very fine carbonate threads; common fine and very fine roots; common fine and many very fine pores; clear boundary.
115-144	Cb2	Light brownish gray (10YR 6/2) silt loam, grayish brown (10YR 5/2) moist; massive; friable; common fine and very fine pores; abrupt boundary.
		Soil 4
144-157	Ab3	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to moderate medium and fine granular; friable; common fine and many very fine pores; clear boundary.
157-170	ACb3	Grayish brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2) moist; weak fine subangular blocky structure; very friable; common fine and many very fine pores; clear boundary.
170-211	Cb3	Light brownish gray (10YR 6/2) loam, grayish brown (10YR 5/2) moist; massive; very friable; many very fine pores; abrupt boundary.
		Soil 5
211-220	Ab4	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to moderate medium and fine granular; very friable; common very fine pores; clear boundary.
220-223	Cb4	Light brownish gray (10YR 6/2) loam, grayish brown (10YR 5/2) moist; massive; very friable; many very fine pores; abrupt boundary.
		Soil 6
223-240	Bkb5	Light brownish gray (10YR 6/2) silt loam, grayish brown (10YR 5/2) moist; moderate fine prismatic structure parting to moderate fine subangular blocky structure; friable; common very fine carbonate threads; common fine and many very fine pores; clear boundary.
240-260	BCkb5	Light brownish gray (10YR 6/2) loam, grayish brown (10YR 5/2) moist; moderate fine subangular blocky structure; very friable; few very fine carbonate threads; few very fine pores; clear

		boundary.
260-316	Cb5	Light brownish gray (10YR 6/2) loamy very fine sand, grayish brown (10YR 5/2) moist; massive; very friable; few fine pores; abrupt boundary.
		Soil 7
316-360	Bkb6	Grayish brown (10YR 5/2) loam, dark grayish brown (10YR 4/2) moist; weak fine prismatic structure parting to moderate fine subangular blocky structure; friable; few very fine carbonate threads; common fine and many very fine pores; gradual boundary.
360-385	BCkb6	Light brownish gray (10YR 6/2) loam, grayish brown (10YR 5/2) moist; moderate fine subangular blocky structure; very friable; few very fine carbonate threads; many very fine pores; clear boundary.
385-440	Cb6	Light brownish gray (10YR 6/2) loam, grayish brown (10YR 5/2) moist; massive; very friable; few fine pores; abrupt boundary.
		Soil 8
440-448	Ab7	Dark grayish brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to moderate medium and fine granular; very friable; many very fine pores; clear boundary.
448-460	ACb7	Grayish brown (10YR 5/2) loam, dark grayish brown (10YR 4/2) moist; weak fine subangular blocky structure; very friable; many very fine pores; clear boundary.
460-496	Cb7	Light brownish gray (10YR 6/2) very fine sand, grayish brown (10YR 5/2) moist; massive; very friable; common very fine pores; abrupt boundary.
		Soil 9
496-512	Ab8	Dark grayish brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to moderate medium and fine granular; very friable; many very fine pores; clear boundary.
512-530	ACb8	Grayish brown (10YR 5/2) loam, dark grayish brown (10YR 4/2) moist; weak fine subangular blocky structure; very friable;

		common very fine pores; clear boundary.
530-560+	Cb8	Light brownish gray (10YR 6/2) very fine sand, grayish brown (10YR 5/2) moist; massive; very friable; common very fine pores.

Table 3. Description of Core WR-3.

Landform: T-2 Terrace
Slope: 1%
Parent material: Alluvium
Remarks: Soil organic matter from the upper 10 cm of the Ab1, Ab2 and Bkb3 horizons yielded AMS radiocarbon ages of 1270±20, 582± 35, and 7390±35 respectively.

Depth (cm)	Soil Horizon	Description
		Soil 1
0-10	A	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; moderate fine subangular blocky structure parting to moderate medium and fine granular; friable; many fine and very fine roots; common fine and many very fine pores; clear boundary.
10-25	AC	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak moderate and fine granular structure; very friable; many fine and very fine roots; common fine and many very fine pores; gradual boundary.
25-56	C	Grayish brown (10YR 5/2) loam, dark grayish brown (10YR 4/2) moist; massive; friable; many fine and very fine roots; many very fine pores; abrupt boundary.
		Soil 2
56-75	Ab1	Very dark grayish brown (10YR 3/2) silt loam, very dark brown (10YR 2/2) moist; weak fine subangular blocky structure parting to moderate medium and fine granular; very friable; many fine and very fine roots; common fine and many very fine pores; clear boundary.
75-95	ACb1	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak medium and fine granular structure; very friable; common fine and many very fine roots; common fine and many fine pores; gradual boundary.
95-120	C1b1	Grayish brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2) moist; massive; very friable; common fine and many very fine roots; common very fine pores; abrupt boundary.
120-305	C2b1	Light brownish gray (10YR 6/2) silt loam, grayish brown (10YR 5/2) moist; massive; very friable; common very fine roots; few fine and

		many very fine pores; abrupt boundary.
		Soil 3
305-315	Ab2	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; moderate fine subangular blocky structure parting to moderate medium and fine granular; friable; many fine and very fine pores; clear boundary.
315-325	ACb2	Grayish brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2) moist; weak fine subangular blocky structure; friable; common fine and many very fine pores; clear boundary.
325-368	Cb2	Grayish brown (10YR 5/2) loam, dark grayish brown (10YR 4/2) moist; massive; very friable; common fine and very fine pores; abrupt boundary.
		Soil 4
368-390	Bkb3	Light brownish gray (10YR 6/2) silt loam, grayish brown (10YR 5/2) moist; weak fine prismatic structure parting to moderate fine subangular blocky; friable; few very fine carbonate threads; common fine and many very fine pores; clear boundary.
390-410	BCb3	Light brownish gray (10YR 6/2) loam, grayish brown (10YR 5/2) moist; moderate fine subangular blocky; very friable; common fine and many very fine pores; gradual boundary.
310-490+	Cb3	Light brownish gray (10YR 6/2) very fine sand, grayish brown (10YR 5/2) moist; massive; very friable; common very fine pores.

Table 4. Description of Core WR-4.

Landform: T-1 terrace
Slope: 1%
Parent material: Alluvium
Remarks: Soil organic matter from the upper 10 cm of the Ab1, Bkb2, Bkb3, Ab4, Ab5, Ab6 and Ab7 horizons yielded AMS radiocarbon ages of 1020±20, 1650± 5, 1590±25, 1280±20, 1375±20, 410±25, and 1360±20 respectively.

Depth (cm)	Soil Horizon	Description
		Soil 1
0-10	A	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to moderate and fine granular; friable; many fine and very fine roots; common fine and many very fine pores; clear boundary.
10-20	AC	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; moderate fine granular structure; very friable; many fine and very fine roots; many fine and very fine pores; gradual boundary.
20-50	C1	Grayish brown (10YR 5/2) loam, dark grayish brown (10YR 4/2) moist; massive; very friable; many fine and very fine roots; many very fine pores; gradual boundary.
50-107	C2	Light brownish gray (10YR 6/2) very fine sand, grayish brown (10YR 5/2) moist; massive; very friable; common very fine roots; many very fine pores; abrupt boundary.
		Soil 2
107-120	Ab1	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to moderate medium and fine granular; very friable; few very fine roots; many very fine pores; clear boundary.
120-135	ACb1	Grayish brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2) moist; weak fine granular structure; very friable; common fine and many very fine roots; common fine and many fine pores; gradual boundary.
135-161	Cb1	Grayish brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2) moist; massive; very friable; few very fine roots; common very fine pores; abrupt boundary.

		Soil 3
161-187	Bkb2	Gray (10YR 6/1) silt loam, gray (10YR 5/1) moist; weak fine prismatic structure parting to moderate medium and fine subangular blocky; friable; few very fine carbonate threads and few patchy films on ped faces; few medium, common fine and many very fine pores; clear boundary.
187-197	BCb2	Light brownish gray (10YR 6/2) silt loam, grayish brown (10YR 5/2) moist; weak fine subangular blocky; very friable; few very fine roots; common fine and many very fine pores; gradual boundary.
197-210	Cb2	Light brownish gray (10YR 6/2) silt loam, grayish brown (10YR 5/2) moist; massive; very friable; few very fine roots; common fine and very fine pores; abrupt boundary.
		Soil 4
210-240	Bkb3	Gray (10YR 6/1) silt loam, gray (10YR 5/1) moist; weak medium subangular blocky; friable; few very fine carbonate threads; few very fine roots; few medium, common fine and many very fine pores; clear boundary.
240-250	BCb3	Light brownish gray (10YR 6/2) silt loam, grayish brown (10YR 5/2) moist; weak fine subangular blocky; very friable; common very fine pores; gradual boundary.
250-288	Cb3	Light brownish gray (10YR 6/2) loamy very fine sand, grayish brown (10YR 5/2) moist; massive; very friable; common very fine pores.
		Soil 5
288-305	Ab4	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to moderate medium and fine granular; friable; many very fine pores; clear boundary.
305-314	Cb4	Light brownish gray (10YR 6/2) loamy very fine sand, grayish brown (10YR 5/2) moist; massive; very friable; few very fine pores; abrupt boundary.
		Soil 6
314-327	Ab5	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown

		(10YR 3/2) moist; weak fine subangular blocky structure parting to moderate medium and fine granular; friable; many very fine pores; clear boundary.
327-342	Cb5	Light brownish gray (10YR 6/2) loam, grayish brown (10YR 5/2) moist; massive; very friable; few very fine pores; abrupt boundary.
		Soil 7
342-365	Ab6	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to moderate medium and fine granular; friable; many very fine pores; clear boundary. Contains charcoal layer at 348cm.
365-406	Cb6	Light brownish gray (10YR 6/2) very fine sand, grayish brown (10YR 5/2) moist; massive parting to single grain; very friable; few very fine pores; abrupt boundary.
		Soil 8
406-420	Ab7	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to moderate medium and fine granular; friable; many very fine pores; clear boundary.
420-430+	Cb7	Light brownish gray (10YR 6/2) loamy sand, grayish brown (10YR 5/2) moist; massive; friable; few very fine pores; abrupt boundary.

APPENDIX 3. Core descriptions from the White River valley at Slim Butte Road

Table 1. Description of Core SB-2.

Landform: Floodplain (T-0b)
Slope: 1%
Parent material: Alluvium
Remarks: Charcoal from the C horizon at a depth of 109 cm yielded an AMS radiocarbon age of 75±20. Soil organic matter from the upper 10 cm of the Akb horizon yielded an AMS radiocarbon age of 2155±25.

Depth (cm)	Soil Horizon	Description
		Soil 1
0-10	A	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; moderate medium and fine granular structure; friable; common medium, many fine and very fine roots; clear boundary.
10-129	C	Stratified, 3-10cm-thick beds of grayish brown (10YR 5/2) silty clay, yellowish brown (10YR 5/4) clay, and light brownish gray (10YR 6/2) silt loam; massive; firm (silty clay), very firm (clay), and friable (silt loam); common fine and many very fine roots; common fine and many very fine pores; abrupt boundary.
		Soil 2
129-150	Akb	Dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; moderate fine subangular blocky structure parting to moderate medium granular; friable; few very fine carbonate threads; few very fine roots; few fine and many very fine pores; clear boundary.
150-208	C1b	Grayish brown (10YR 5/2) silty clay, dark grayish brown (10YR 4/2) moist; massive; firm; few very fine roots; many very fine pores; abrupt boundary.
208-330+	C2b	Grayish brown (10YR 5/2) clay loam, dark grayish brown (10YR 4/2) moist; massive; firm; many very fine pores. Contains few 1cm-thick beds of light gray (10YR 7/2) very fine sand, light brownish gray (10YR 6/2) moist; massive; friable.

Table 2. Description of Core SB-4.

Landform: T-1 Terrace
Slope: 1%
Parent material: Alluvium

Depth (cm)	Soil Horizon	Description
		Soil 1
0-10	A	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; moderate medium and fine granular; very friable; many fine and very fine roots; clear boundary.
10-28	C	Grayish brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2) moist; massive; very friable; common fine and many very fine roots; many very fine pores; abrupt boundary.
		Soil 2
28-38	Ab	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; moderate medium and fine granular; friable; common fine and many very fine roots; clear boundary.
38-50	ACb	Grayish brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2) moist; weak medium and fine granular structure; very friable; common fine and many very fine roots; gradual boundary.
50-190	C1b	Light brownish gray (10YR 6/2) silt loam, grayish brown (10YR 5/2) moist; massive; very friable; few fine and common very fine roots; many very fine pores; gradual boundary.
190-380	C2b	Grayish brown (10YR 5/2) sandy loam, dark grayish brown (10YR 4/2) moist; massive parting to single grain; very friable; gradual boundary.
380-480+	C3b	Pale brown (10YR 6/3) medium to very coarse sand, brown (10YR 5/3) moist; single grain.

Table 3. Description of Core SB-3.

Landform: T-2 Terrace
Slope: 1%
Parent material: Alluvium
Soil organic matter from the upper 10 cm of the Akb1, Akb2, and Akb3 horizons yielded AMS radiocarbon ages of 1800±20, 2455±20, and 2695±30, respectively.

Depth (cm)	Soil Horizon	Description
		Soil 1
0-20	A	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to moderate medium and fine granular; friable; common fine and many very fine roots; many very fine pores; clear boundary.
20-40	AC	Grayish brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2) moist; weak fine subangular blocky structure parting to moderate medium and fine granular; friable; common fine and many very fine roots; many very fine pores; gradual boundary.
40-75	C1	Grayish brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2) moist; massive; friable; common fine and many very fine roots; many very fine pores; gradual boundary.
75-192	C2	Light brownish gray (10YR 6/2) silt loam, grayish brown (10YR 5/2) moist; massive; friable; common very fine roots; many very fine pores; abrupt boundary.
		Soil 2
192-225	Akb1	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; moderate medium and fine subangular blocky structure parting to moderate medium granular; friable; few fine and very fine carbonate threads and flecks; many fine and very fine roots; many very fine pores; clear boundary.
225-272	Cb1	Light brownish gray (10YR 6/2) silt loam, grayish brown (10YR 5/2) moist; massive; very friable; few very fine roots; few fine and many very fine pores; abrupt boundary.
		Soil 3
272-295	Akb2	Grayish brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2) moist; moderate medium subangular blocky structure parting to moderate medium granular; friable; very few, fine carbonate

		threads; few very fine roots; common fine and many very fine pores; clear boundary.
295-383	Cb2	Light brownish gray (10YR 6/2) silt loam, grayish brown (10YR 5/2) moist; massive; very friable; many very fine pores; abrupt boundary.
		Soil 4
383-400	Akb3	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; moderate medium subangular blocky structure parting to moderate medium granular; friable; few, fine carbonate threads and flecks; few very fine roots; common fine and many very fine pores; clear boundary.
400-485	C1b3	Light brownish gray (10YR 6/2) silt loam, grayish brown (10YR 5/2) moist; massive; friable; many very fine pores; abrupt boundary.
485-550+	C2b3	Grayish brown (10YR 5/2) sandy loam, dark grayish brown (10YR 4/2) moist; massive; very friable.

Part II: Nebraska Buried Sites GIS – User's Guide

Nebraska Department of Transportation Project SRP-P1(20) M100

"A Statewide Geographic Information System (GIS) as a Predictive Tool for Locating Deeply Buried Archeological Deposits in Nebraska: Phase II"

September 2021

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DISCLAIMER:

This project is designed to evaluate the geologic ***potential*** for buried cultural deposits in Nebraska. This GIS resource is simply a tool to determine whether proposed areas of potential effect (APE) possess a greater or lesser likelihood of requiring additional subsurface exploration to establish the presence of buried archeological properties. The product should never be used solely to offer determinations about the definitive presence or absence of cultural resources from the perspective of compliance with Section 106 of the National Historic Preservation Act and any other related state or federal laws and regulations. History Nebraska and the University of Kansas does not assume professional liability for parties using this product to make Section 106 determinations without additional investigations.

1. Introduction

1.1 Scope and Purpose

This user's guide is intended as an introduction to the use of the *Nebraska Buried Sites GIS*, developed by the Nebraska State Archeology Office (History Nebraska) and the Kansas Geological Survey under NTRC Grant Project SRP-P1(20) M100, "A Statewide Geographic Information System (GIS) as a Predictive Tool for Locating Deeply Buried Archeological Deposits in Nebraska: Phase II."

This GIS is intended for use by cultural resource specialists in the initial phase of determining whether targeted investigations for deeply buried sites are necessary during project planning and development. The GIS is designed to enhance the ability to predict where these types of resources may or may not occur. It is specifically intended for use in Nebraska Department of Transportation (NDOT) and the Federal Highway Administration (FHWA) undertakings, but is anticipated to also prove useful for cultural resource specialists in other agencies, as well as geomorphologists conducting research in the state.

1.2 Software Notes

The *Nebraska Buried Sites GIS* was developed using ESRI ArcGIS Pro 2.8.3 and published as a Web Map to ArcGIS Online.

2. Access

2.1 Accessing the Map

The Nebraska Buried Sites Web Map is available to members of the History Nebraska Buried Sites ArcGIS Online Group. To request access, email courtney.ziska@nebraska.gov or submit an invitation request on ArcGIS Online. To protect recorded archeological site locations, the Nebraska State Archeology Office's data is protected by state statute. We reserve the right to restrict access to specific localities and site location information when deemed necessary.

3. Navigation

3.1 Layers

The *Nebraska Buried Sites GIS* contains several Reference Layers to assist users in pinpointing a particular location or area of interest. These layers are listed below. Click the filter button below an individual layer to zoom to a feature of interest.

Reference Layers:

NE_Towns – Filter by town/city name in NAME field (i.e., NAME is Lincoln).

Counties – Filter by county name in COUNTY_NAM field.

Watersheds – Filter by watershed in WATERSHED field.

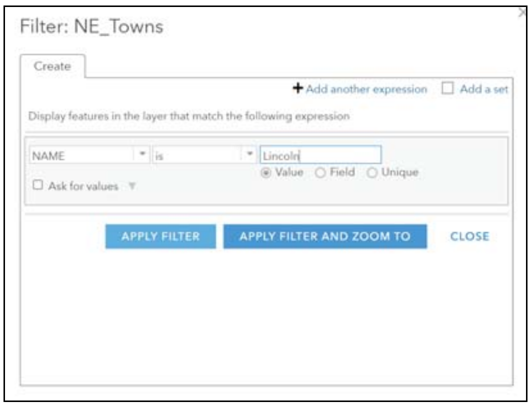
Legal – Section Township Range – Filter by legal description in Sec_T_R field.

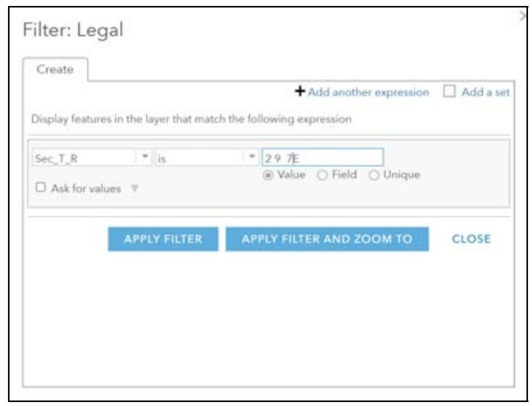
Note - Search must match field character format. Examples:

-Section 2, Twn 9N, Rng 7E = 2 9 7E [2_9_ _7E, when _ represents a space]

-Section 10, Twn 10N, Rng 7E = 10 10 7E [10_10_ _7E, when _ represents a space]

-Section 19, Twn 22N, Rng 55W = 19 22 55W [19_22_55W, when _ represents a space]





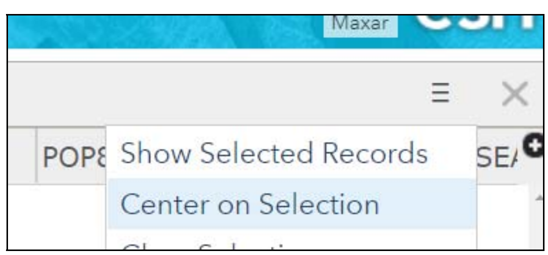
Click *Apply Filter and Zoom To* Location.

For more information on navigating in Map Viewer Classic, visit https://doc.arcgis.com/en/arcgis-online/reference/view-maps.htm.

3.2 Navigation by Attribute Table

3.2.1 Open Feature Layer Table

1. Scroll through table, and select/highlight feature of interest.
2. Click the Options dropdown menu in the upper right-hand corner of the table, and *Center on Selection*.



3.2.2 Adding Shapefiles

Shapefiles depicting an area of interest may be added to the map by clicking the Add button from the main menu bar and selecting *Add Layer from File*.
**Note: Shapefiles should be contained within a zipped archive/folder.*

4. The Geoarcheological Data

4.1 Layers

The geoarcheological data is organized by county. Each county group layer contains two feature classes ("potential" and "other") that spatially illustrate the potential for buried cultural resources on the basis of parent material and landscape position/modification. An additional layer depicts the referenced localities  used to assess assigned potential ratings.

Localities are areas where geoarcheological field data is available from previous research conducted in the state. The data from these sites were referenced in the assignment of potential for buried cultural resources. This data typically includes a detailed description of the soil-stratigraphic record of a particular location, along with photos and illustrated soil profiles. This data is based on the in-field examination of soil cores or cuts along stream banks and other eroded areas by a geomorphologist.

The geologic **potential** for buried cultural resources, as depicted for each county, was assigned to different landform-sediment assemblages (LSAs) based on consideration of four factors, including 1) the age of sedimentary deposits, 2) the soil-stratigraphic record, 3) the depositional environment, and 4) the drainage conditions. For more information on LSAs, the methodology used in the creation of the potential layers, and descriptions of the assigned categories, see the final project report in Part I of this document.

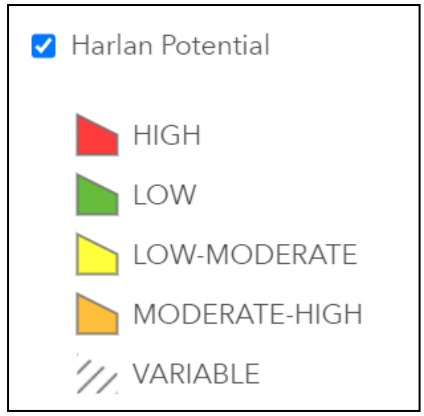
4.2 Visibility

The Watershed, County, and other reference layers are visible depending on the extent to which a user is zoomed in on the map. Locality layers are set to appear when zoomed in beyond 1:399,999. Watershed potential layers are set to appear when zoomed in beyond 1:250,000. *[These ranges may be changed, but changes may affect map performance.]*

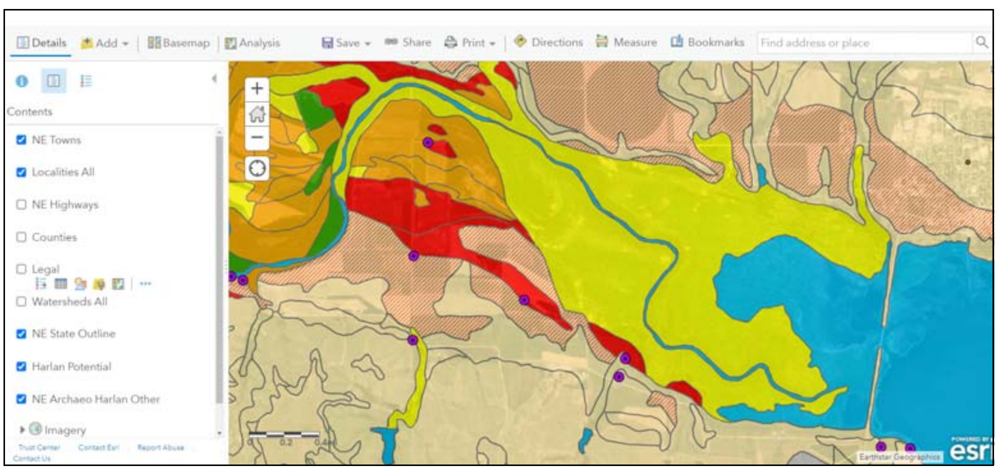
4.3 Exploring the Geoarcheological Data

4.3.1 {*County*} Potential Layer

The geologic potential for buried cultural resources of a given area is depicted based on the assignment of four categories: Low, Low-Moderate, Moderate-High, or High. In addition to scoring, a "variable" assignment was used for select map units associated with a range of different landscape positions (i.e., different LSAs) that have varying potential (e.g., upland drainageway vs. terrace).



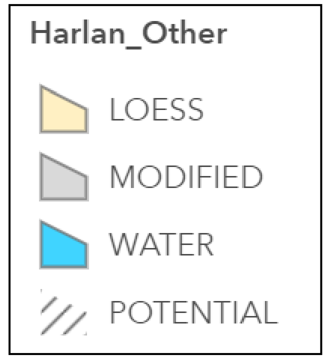
The attribute table of this layer consists of details related to the assignment of scores resulting in the final potential rating. The fields contain data related to flood frequency, drainage, geomorphology/landscape position, soil horizonation, and parent material. For more information on these fields and how scores were calculated, see the final project report in Part I of this document.



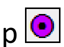
4.3.2 {*County*} Other Layer

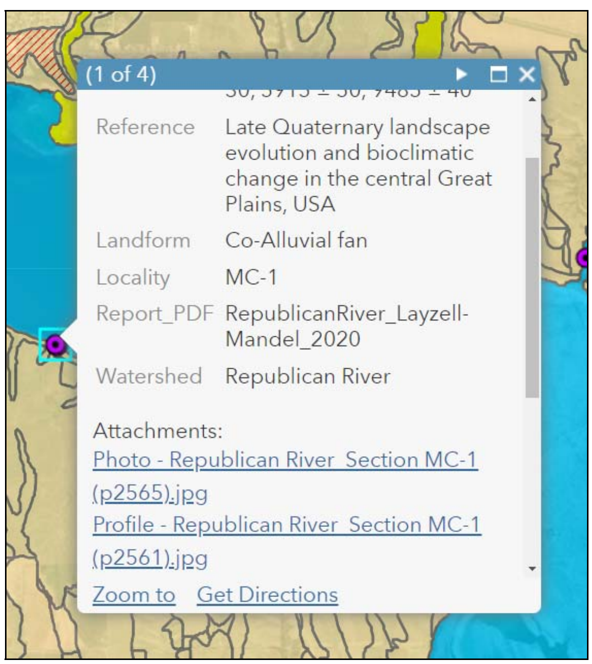
This layer consists of discrete categories of map units associated with loess, till, alluvium (in upland settings; typically, paleoterraces), and outwash parent materials. A general "uplands" category includes map units associated with residual soils, rock outcrops, and colluvium (not footslopes). The "modified" category includes soils modified by anthropogenic activity (e.g., urban soils, quarries, landfills, etc.), and finally, a "water" category includes features such as rivers, lakes, sewage ponds, etc. Each unique category is depicted in a different color, with the color scheme maintained throughout each of the watersheds.

Although map units in the "other" feature class were not scored, certain geomorphic descriptions suggest that potential for buried cultural resources may be present. Therefore, in addition to parent material (i.e., loess, till, etc.) and "modified" categories, a "potential" category was created in this feature class for these specific map units and notes provided pertaining to the nature of the potential.



4.3.3 <u>Localities Layer</u>

Locality data collected from across the state through the course of geoarcheological studies is available in the Localities layer. To explore the data available for each specific locality, click a locality feature on the map  to launch the popup. Each popup will contain the available data for a locality, including its name, landform type, and chronologic dates available for associated buried soils, the report reference, and any photo, profile, and report attachments. Click the .jpg and/or .pdf links to view these file attachments in a new window. *[Page numbers included in attachment file names (i.e., p67, p204, etc.) indicate page location of photo/profile in attached referenced report.]*

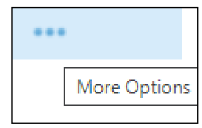


Note: Not all fields and attachment types will be available for each locality. For example, some localities may not have an associated radiocarbon chronology, due to the absence of datable material during the original research visit. Others may not have photos and/or profiles, due to these not being included in the final report, as referenced. In addition, be aware that the quality of the image and report attachments is dependent on the quality of the original hard-copy or scanned document available.

5 Maps

5.1 Print

In the Main Menu, you can choose to print a map showing your current view with or without a legend. Turn layers on or off to remove features from print display. Remove items from legend by selecting *Hide in Legend* under each layer's *More Options* button.



6 Additional Information

6.1 Updates

As future funding, research, and time allow, the *Nebraska Buried Sites GIS* is anticipated to be updated with revised values of geologic potential based on the addition of new geoarcheological locality data. These updates are the best means of ensuring that the data presented in the GIS is as accurate as possible for use in cultural resource planning. Please contact the State Archeology Office at History Nebraska for any updates that may be available (see contact information below).

6.2 Questions and Comments

Questions and comments concerning the Nebraska Buried Sites GIS may be directed to the State Archeology Office at History Nebraska (Nebraska State Historical Society):

Courtney Ziska
State Archeology Office
History Nebraska
5050 N. 32nd Street
Lincoln, NE 68504
Email: courtney.ziska@nebraska.gov

Part III: Bibliography of Nebraska Geoarcheology

Nebraska Department of Transportation Project SRP-P1(20) M100

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