A Geoarchaeological Overview of South Dakota and Preliminary Guidelines for Identifying and Evaluating Buried Archaeological Sites

Final Report

by
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A geoarchaeological overview of South Dakota identifies the landforms and sedimentary environments where buried archaeological deposits are most likely to be preserved. A preliminary estimate, based on geological map data, is that at least 18% of the state consists of landscapes with significant concentrations of alluvial, colluvial, and eolian sedimentary deposits with buried site potential. Each sedimentary environment sets different conditions for buried site potential, including not only the burial of archaeological deposits, but also their preservation from subsequent erosion. Buried site potential, defined in terms of geological processes and their effect on the archaeological record, can be high (suitable for well preserved, stratified sites), moderate (suitable for burial but subject to disturbance), and low (high energy, erosional environments).

Evaluating buried site potential can be approached through map and imagery interpretation, but conclusive identification requires fieldwork. Latest Wisconsinan and Holocene sediments with potential to contain buried archaeological deposits are commonly at depths greater than shallow (<1 m) testing or cutbank examination can expose, and thus require trenching, coring, or augering. Trenching and augering at present are the best methods for detecting buried sites when the thickness of high-to-moderate potential sediment exceeds 1 m. The decision to perform deep testing should be should be based on the horizontal and vertical dimensions of the Area of Potential Effect (APE), the buried site potential of landform and sediments within the APE, and local and regional site density. From a cost-benefit analysis, low-impact undertakings probably do not warrant the additional costs of subsurface testing of high-moderate potential landforms, unless the undertaking is passing through an area of known significant sites.

The Preliminary Guidelines for Identifying and Evaluating Buried Archaeological Deposits in South Dakota defines the buried site potential of the state's landscapes, landforms, and sedimentary environments. A staged approach is proposed; a pre-field desktop assessment to establish the need for and extent of buried site potential in the APE, a geoarchaeological assessment to confirm the presence and determine the horizontal and vertical extent of high to moderate potential sediments, and an archaeological assessment to seek buried sites within those deposits. The geoarchaeological and archaeological assessments may proceed concurrently, or the geoarchaeological assessment may be conducted first. Further discussion within the South Dakota historic preservation community is needed to determine the kinds of undertakings to which the guidelines will be applied.

PART I: Introduction

Great Plains landscapes have been geologically dynamic throughout the late Pleistocene and Holocene, resulting in the burial and erosion of archaeological sites (Albanese and Frison 1995; Artz 1995; Mandel 1995). Unless fortuitously exposed in a cutbank or by construction, buried sites are difficult to discover, but they are often among our most significant archaeological resources, as exemplified in South Dakota by Lange-Ferguson, Jim Pitts, Lightning Springs, and others (Keyser and Davis 1984; Sellet et al. 1995; Hannus 1985). Sites sealed by layers of alluvium or eolian deposits often have better integrity than surface deposits exposed to cultivation. In addition, sites with multiple buried components provide important information on cultural change through time.

Section 106 of the National Historic Preservation Act (NHPA) requires agencies to take into account significant historic properties affected by Federally-funded, licensed or permitted undertakings. Given their significance, it is reasonable to expect agencies and their archaeological consultants to employ survey strategies aimed at identifying buried sites. Survey techniques that entail only surface walkover are insufficient in geological contexts such as stream valleys and eolian sediments, where geologic processes can act to bury archaeological sites.

As in many western states, where arid and semi-arid climates result in sparse vegetation cover and good surface visibility, archaeological survey in South Dakota is conducted primarily by surface survey. Buried sites are identified primarily where subsurface deposits are exposed, as in stream cutbanks, or when discovered when testing to evaluate a surface-visible site. This raises the possibility that, if not exposed at the surface or in a cutbank, buried sites may be missed by survey. If deeply buried enough, they may be missed if test pits and other excavations only penetrate to depths necessary to evaluate surface-visible archaeological deposits.

BACKGROUND

Published guidelines for cultural resource surveys and survey reports in South Dakota (SHPO 2005) define three levels of survey. Level I is a literature and records review that assembles existing knowledge about the proposed survey area but does not include field work. Level II surveys are used primarily in the context of linear surveys (pipelines, roads, transmission lines). Representative portions of the proposed project area are surveyed as a means of planning an intensive survey. Level II surveys are not common (Paige Olson, personal communication, 2011).

Level III surveys are intensive ("100 percent") surveys of the project APE. Subsurface testing to discover archaeological sites is included in the guidelines, which state,

> "Survey transects must be no more than 30 meters (100 feet) apart… The report must explain survey methods and the rationale for their use, for instance, why the archaeologist did or did not conduct subsurface testing…. Based on professional judgment, the principal investigator may carry out additional minimal subsurface testing as necessary. If the principal investigator feels more information is required than what is revealed by the ground surface or minimal subsurface testing, e.g. shovel probing, augering…, the principal investigator should consult SHPO and others to develop an appropriate strategy for gaining necessary information with minimal damage to the site. Extensive testing during survey within sites is not recommended, though some testing is often warranted as an exploratory tool within and between features or activity areas and to determine boundaries. All decisions to test or not to test should be justified" (SHPO 2005:9).

The guidelines do not address subsequent phases of investigation, such as testing to evaluate National Register eligibility, or large-scale excavation to mitigate adverse effects of a National-Register-eligible property. It is during these phases that most buried-site investigations are currently undertaken in South Dakota. Investigations that attempt to identify buried site potential during or in advance of initial surveys are rare (Fosha and Albanese 1998; Hajic 2008; Sundstrom et al. 1999). Buried sites are usually encountered in erosional cuts (Artz and Toom 1985; Hannus 1985; Keyser and Davis 1984), or during excavation of surface-visible sites (Black and Metcalf 1985; Hannenberger et al. 2010).

The South Dakota SHPO currently considers the need for deep testing to identify or evaluate sites on a case by case basis. The consideration is often made after-the-fact. For example, agency and tribal review of a Level III intensive survey report will result in a recommendation that subsurface testing, or additional testing, is necessary before consultation on the effects of the undertaking on cultural resources can be concluded. Such recommendations may come from the undertaking's lead Federal agency, from the State Archaeologist for state-funded projects, from SHPO, or from a Tribal Historic Preservation Office (THPO). The recommendation generally results in the consultant returning to the field to conduct the investigation. Additional costs are incurred and consultation is delayed.

In some cases, the recommendation meets opposition from the developer, the archaeological consultant, or an agency that is party to the consultation. Negotiating an outcome increases costs, requires time, and sometimes becomes acrimonious. A recent example from South Dakota is culture resource investigations for the proposed DM&E railroad (Eigenberger et al. 2009).

Similar situations arise in many other states. In some cases, the failure of a surface or near-surface intensive survey to identify deeply buried archaeological deposits result in very large, unanticipated costs and delays. Examples include the Mondrian Tree site (32MZ58), on the Missouri River, in North Dakota, impacted by the Northern Border Pipeline (Toom and Gregg 1983); a complex of sites on the Ohio River in Ohio, impacted by the Argosy Lawrenceburg Casino (Creasman 1996; Stafford and Creasman 2002); and numerous sites impacted by the Avenue of the Saints highway construction project on the Mississippi River in Missouri (Hajic et al. 1996; Morrow 1997). In each case, an initial intensive survey using traditional pedestrian and shallow testing methods had been completed. Section 106 consultation led to the conclusion that the surveys were not adequate to locate potential buried sites in these major river valleys. Additional investigation identified highly significant multiple components sites, but also resulted in construction delays.

There are also success stories, where geoarchaeological investigations, conducted as part of the initial, intensive survey, resulted in the discovery of deeply buried cultural deposits. In these cases, early discovery greatly increased the lead time needed to plan for treatment of the historic property, and also allowed the developer up-front notice of total costs. Examples include the Eisele Hill site (13MC15) in Iowa (Artz et al. 1995), and complexes of sites impacted by the Rocky Mountains Express natural gas pipeline in Missouri (Artz 2007) and Indiana (Artz et al. 2007, 2008). In both instances, deep testing was a requirement of the lead agency or their engineering consultant, and was driven, at least in part, by the existence of state guidelines calling for geoarchaeological investigation during or prior to intensive survey (Association of Iowa Archaeologist 1993; Division of Historic Preservation 2007).

OBJECTIVES

The following report has two objectives. First is a geoarchaeological overview of the state, identifying where buried sites are known to occur, and what kinds of geological contexts are most likely to contain as-yet-undiscovered buried sites. The second is to develop a set of methodological best practices that South Dakota's State Historic Preservation Office (SHPO) can recommend to agencies and archaeologists as guidelines for ensuring that a reasonable and good faith effort is made to identify and evaluate buried sites.

Part II, the geoarchaeological overview, begins with a statewide overview of geology and geomorphology as encountered in the archaeological regions defined in the *South Dakota State Plan for Archaeological Resources* (Figure 1; Winham and Hannus 1990). Emphasis is given to the distribution of alluvial and eolian deposits among regions, because many such deposits are late Wisconsinan to Holocene in age, and often sufficiently thick to contain buried archaeological deposits.

Next, the geoarchaeological overview considers South Dakota landscapes and landforms at the more detailed spatial scales needed for archaeological survey and excavation. A classification of the kinds and regional distribution of landforms is presented. The focus is on the geological processes at work in each landform context, and how these affect the formation, burial, and preservation of archaeological sites. Finally, the geoarchaeological literature of South Dakota is reviewed, identifying studies that define past and current approaches to identifying and evaluating buried sites, and the results obtained.

Part III develops and presents *Preliminary Guidelines for the Identification and Evaluation of Buried Archaeological Sites in South Dakota*. It begins with a review of buried site guidelines from other states, where practices have been developed and pursued to determine the archaeological potential of sediments, and to seek sites within them. Next, the premises and concepts that underlie this project's development of the guidelines are set forth, including both geological and methodological considerations.

The guidelines presented at the end of Part II are designed to be responsive to agency approaches and contractor capabilities, as these currently exist in South Dakota. The guidelines are also informed by the

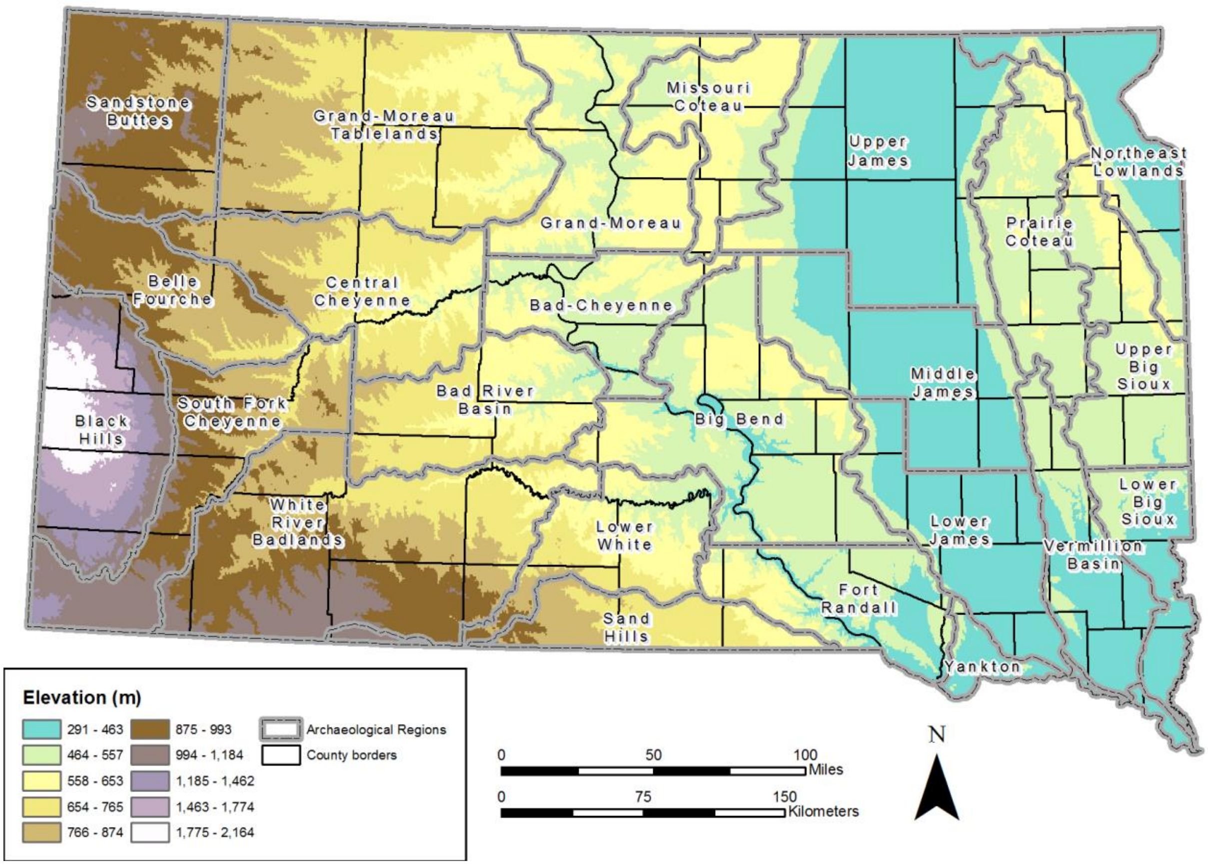


Figure 1. Archaeological regions of South Dakota (Buechler 1983; Winham and Hannus 1990). Base map is a 30 m resolution, United States Geological Survey, National Elevation Dataset digital elevation model.

current state of knowledge, presented in Part I, regarding the processes of erosion and deposition that are involved in the burial and preservation of buried sites in South Dakota.

This study was conducted by the University of Iowa Office of the State Archaeologist with funding from the State Historical Society of South Dakota, in response to a Request for Proposals issued by that agency. The guidelines were also developed in consultation with a voluntary advisory committee with experience in the state. Through conversation and comments, the committee greatly influenced the document presented here by honing its focus on the geoarchaeological, methodological, and regulatory realities of cultural resource management in South Dakota. The committee was comprised of:

- Paige Olson, South Dakota State Historic Preservation Office, Pierre, SD
- Jim Donohue, South Dakota Archaeological Research Center (ARC), Rapid City, SD
- Mike Fosha, ARC
- Jim Haug, South Dakota State Archaeologist, ARC
- Michael Hilton, U.S. Forest Service,
- Mike Kolb, Strata Morph Geoexploration, Sun Prairie, WI
- Linea Sundstrom, Daystar Research, Shorewood, WI
- Randy Withrow, The Louis Berger Group, Marion, IA

In addition, Andy Clark (ARC), Austin Buhta (Augustana College) and Jeff Buechler (Dakota Research Services, Rapid City, SD) commented on the draft guidelines.

ACKNOWLEDGMENTS

The author gratefully acknowledges the support of the voluntary advisory committee, named above. Jim Haug and Jane Watts at ARC provided access to South Dakota's GIS and electronic documents archives, without which this project would not have been possible. Terry Erickson and John Weeldrier at the South Dakota Department of Transportation shared their knowledge, and provided access to, subsurface drilling information for bridges in the state. At OSA, Melanie Riley and Kat Rocheford assisted with GIS data compilation, and John Hall was a tower of patience and exactitude through the arduous task of compiling GIS data, map and figure production, and report editing. Paige Olsen provided the author with essential guidance in understanding the need for, and regulatory context of, the present project. Finally, the author acknowledges his many archaeologist friends and colleagues in the Dakotas who, over the years, have kept his interest in the region alive and informed.

Information Sources

GIS DATASETS

GIS data relevant to the project were obtained from the sources shown in Tables 1 and 2. The following layers were acquired. Most were obtained from on-line clearinghouses including the South Dakota GIS Data Warehouse, the South Dakota Geological Survey website, and the Natural Resources Conservation Service (NRCS) Soil Data Mart. The South Dakota Archaeological Research Center (ARC) provided copies of datasets from its Archaeological Resource Management System (ARMS). These included an Access database and ESRI shapefiles for sites, survey areas, and bibliographic sources in South Dakota.

Table 1. GIS Data Sources.

Name	Format	Source	Description
http://arcgis.sd.gov/server/sdgis/Data.aspx (SD GIS data warehouse)			
County borders	Shapefile	Census 2000	outline of 66 SD counties
Rivers, Streams, Lakes	Shapefile	USGS	National Hydrologic Dataset (NHD)
Local roads	Shapefile	SD DOT	secondary roads
State roads	Shapefile	SD DOT	state highways
Bridges	Shapefile	SD DOT	point locations of South Dakota bridges
Geology	Shapefile	DENR	statewide surface geology map
Missouri River	Shapefile	DENR	major SD drainage
http://www.sdsmt.edu/wwwsarc/resources.html			
Sites	Shapefile	ARC	Archaeological site locations
Surveys	Shapefile	ARC	Archaeological surveys
ARMS-Data	Access database	ARC	Archaeological sites database
Archaeological regions	Shape file	SD SHPO	outline of 24 archaeological regions
http://www.sdgs.usd.edu/digitaldata/index.html			
Digital Elevation Model (DEM)	Raster (Grid)	USGS	National Elevation Dataset (DEM)s
http://soildatamart.nrcs.usda.gov/State.aspx			
SSURGO Soil Survey area	Geodatabase	NRCS	statewide soils base map

Table 2. SSURGO Soils Geodatabases, obtained from the NRCS Soil Data Mart.

County	Database	Source
Bon Homme	sd009_ BonHomme_soildb_SD_2002.mdb	NRCS Soil data mart
Brookings	sd011_Brookings_soildb_SD_2002.mdb	NRCS Soil data mart
Brown	sd013_Brown_soildb_SD_2002.mdb	NRCS Soil data mart
Brule	sd603_Brule_soildb_SD_2002.mdb	NRCS Soil data mart
Buffalo	sd603_Buffalo_soildb_SD_2002.mdb	NRCS Soil data mart
Butte	sd019_Butte_soildb_SD_2002.mdb	NRCS Soil data mart
Charles Mix	sd023_Charles_Mix_soildb_SD_2002.mdb	NRCS Soil data mart
Codington	sd029_Codington_soildb_SD_2002.mdb	NRCS Soil data mart
Davison	sd035_Davison_soildb_SD_2002.mdb	NRCS Soil data mart
Dewey	sd041_Dewey_soildb_SD_2002.mdb	NRCS Soil data mart
Fall River	sd047_Fall_River_soildb_SD_2002.mdb	NRCS Soil data mart
Grant	sd051_Grabt_soildb_SD_2002.mdb	NRCS Soil data mart
Haakon	sd055_Haakon_soildb_SD_2002.mdb	NRCS Soil data mart
Harding	sd063_Harding_soildb_SD_2002.mdb	NRCS Soil data mart
Lawrence	sd081_Lawrence_soildb_SD_2002.mdb	NRCS Soil data mart
McPherson	sd089_Mcpherson_soildb_SD_2002.mdb	NRCS Soil data mart
Meade_N	sd601_Meade_N_soildb_SD_2002.mdb	NRCS Soil data mart
Meade_S	sd600_Meade_S_soildb_SD_2002.mdb	NRCS Soil data mart
Minnehaha	sd099_Minnehaha_soildb_SD_2002.mdb	NRCS Soil data mart
Potter	sd017_Potter_soildb_SD_2002.mdb	NRCS Soil data mart
Sanborn	sd111_Sanborn_soildb_SD_2002.mdb	NRCS Soil data mart
Sully	sd119_Sully_soildb_SD_2002.mdb	NRCS Soil data mart
Todd	sd121_Todd_soildb_SD_2002.mdb	NRCS Soil data mart
Tripp	sd123_Tripp_soildb_SD_2002.mdb	NRCS Soil data mart
Turner	sd125_Turner_soildb_SD_2002.mdb	NRCS Soil data mart

BIBLIOGRAPHIC SOURCES

Relevant literature was obtained from the University of Iowa Libraries, the OSA archives, and the author’s personal library. Most sources, however, were drawn from ARMS. ARMS consists of a Microsoft Access database and two GIS shapefiles, one that shows survey locations, and one that shows site locations. The Access database contains a number of tables. One of these contains bibliographic information (authors, titles, publication year, and place of publication) on reports and other references. The Surveys shapefile is linked to the bibliographic table by a common field, the Archive Number. In the Sites shapefile, individual archaeological sites are depicted as polygons and identified with their Smithsonian Institution Trinomial (SITS) site numbers. The SITS numbers are also used in the Access database to identify information about particular sites. This allows site locations in the GIS data to be linked to records about that site in the Access database.

The authors field of the ARMS bibliography table was searched for individuals with research specialties in geoarchaeology. Such names in the database include earth scientists John Albanese, Robert Brakenridge, Alan Coogan, Rolfe Mandel, James Martin, Michael McFaul, and Everett White, and archaeologists Joe Artz, James Donohue, Dennis Toom, and David Kuehn. The titles field was searched for words that potentially identify reports with an explicitly geoarchaeological intent, including geoarchaeology and geomorphology, as well as keywords that suggest a possibility of deep testing, such as trench, backhoe, auger, testing, evaluation, and mitigation. Finally, titles with names of sites known by the author to have deeply buried components were searched for including Jim Pitts, Lange Ferguson, Beaver Creek Shelter, Lightning Spring, Medicine Crow, and Ray Long.

This initial search returned 74 reports. Of these, 49 were obtained as PDF electronic documents from ARC via File Transfer Protocol (FTP). Others were either in the possession of the author, or obtained from the University of Iowa libraries, interlibrary loan, or the reports’ authors. Eight additional reports were obtained during a July 2011 visit to ARC.

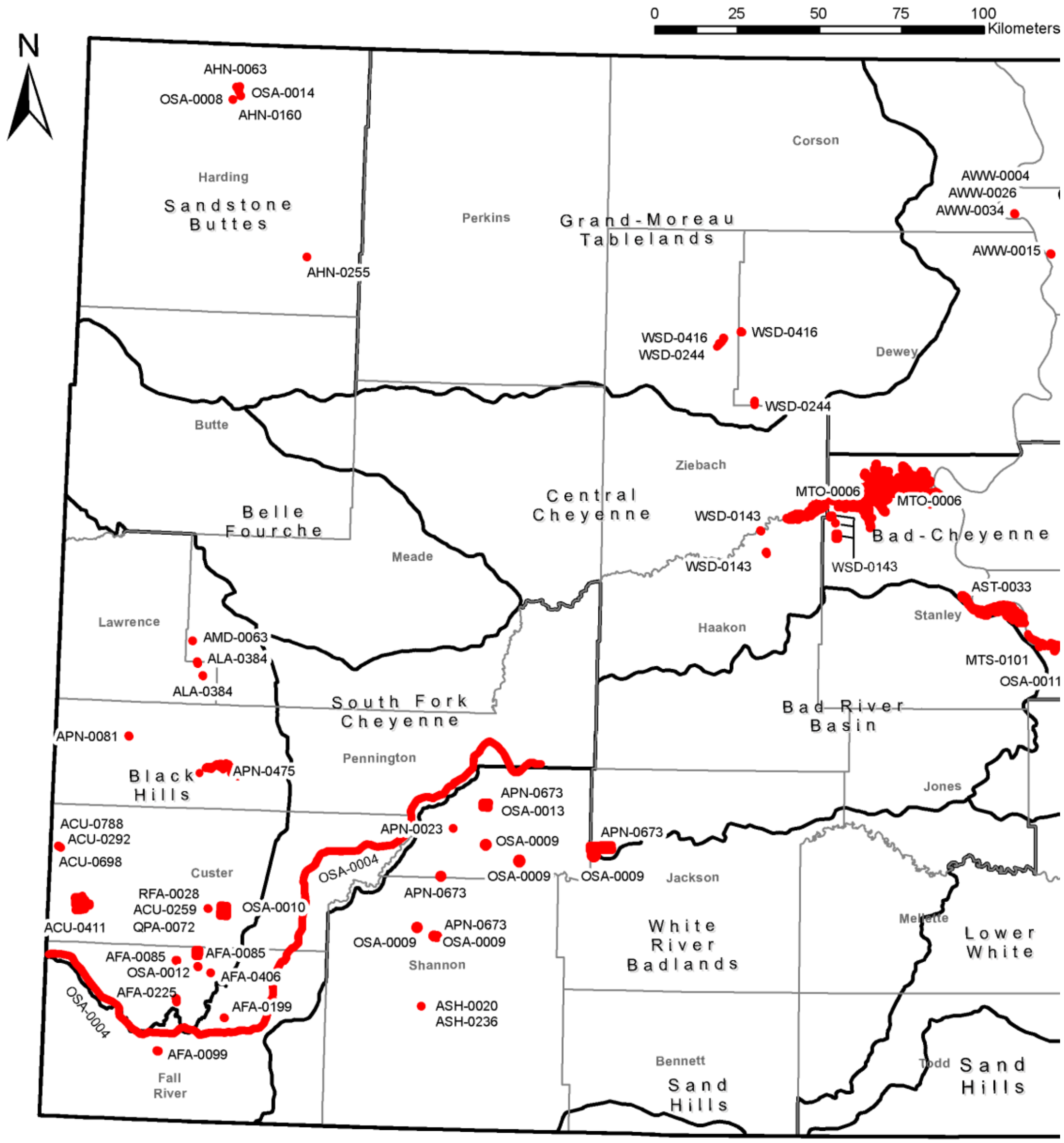
Of the 82 reviewed reports, some did not contain geoarchaeologically-relevant information. A number of reports with “trench” in the title turned out to be surface surveys of locations where trenching for mineral exploration was plan. Others were large scale excavation or construction monitoring reports that contain little or no stratigraphic data.

A GIS dataset called GeoarchReports was created to record the location of geoarchaeologically-relevant studies. Most are archaeological surveys with a corresponding feature in the Surveys shapefile. Other documents were reports on site-specific investigations. Locations of the investigated sites were selected from the Sites shapefile and appended to the GeoarchReports dataset.

Fourteen studies reviewed for this report were not in the ARMS database. These were added to OSA’s copy of ARMS, and assigned “pseudo-ARMS” archive numbers OSA-0001 through OSA-0014. Their locations were manually digitized into GeoarchReports.

Several reviewed studies did not have specific study areas, but were instead generalized to the entire Missouri Trench (Coogan 1987; Coogan and Irving 1959; McFaul 1985, 1986). These have no digital record in GeoarchReports or in the ARMS GIS

Locations of study areas are shown in the Figures 2-3. Only those that, on review, held geoarchaeologically relevant information are listed.



KEY to ARMS Archives Numbers.

ACU-0259	Alex 1991
ACU-0292	Hanenberger and Donohue 1993
ACU-0411	Sundstrom 1999
ACU-0698	Sundstrom et al. 1999
ACU-0788	Smith et al. 1994
AFA-0085	Weston et al. 1982
AFA-0099	Haberman 1980
AFA-0199	Albanese 1986
AFA-0225	Donohue et al. 1996
AFA-0406	Buechler 2009
AHN-0063	Albanese 1985
AHN-0160	Albanese 1999
AHN-0255	Fosha and Albanese 1998
ALA-0384	Sundstrom et al. 2002
AMD-0063	Donohue 1992
APN-0023	Harksen 1974
APN-0081	Buechler 1983
APN-0475	Byrne 1995
APN-0673	Kuehn 2003
ASH-0020	White 1985
ASH-0236	Martin 1983
AST-0033	Artz and Toom 1985
AWW-0004	Ahler et al. 1977
AWW-0015	Ahler et al. 1974
AWW-0026	Sanders et al. 1989
AWW-0034	Toom 1991
MTO-0006	Brakenridge & McReady 1988
MTS-0101	Toom and Steinacher 1980
OSA-0004	Hajic 2008
OSA-0008	Keyser and Davis1984
OSA-0009	Rawlings et al. 2003
OSA-0010	Fredlund 1996
OSA-0012	Agenbroad and Mead 1994
OSA-0013	Kowal 1997
OSA-0014	Over 1936
QPA-0072	Miller et al. 1993
RFA-0028	Abbott 1989
WSD-0143	Fosha 1992
WSD-0244	Pysarsky 2002
WSD-0416	McFaul et al. 2010

Figure 2. Western South Dakota, showing location of reports and publications discussed in text.

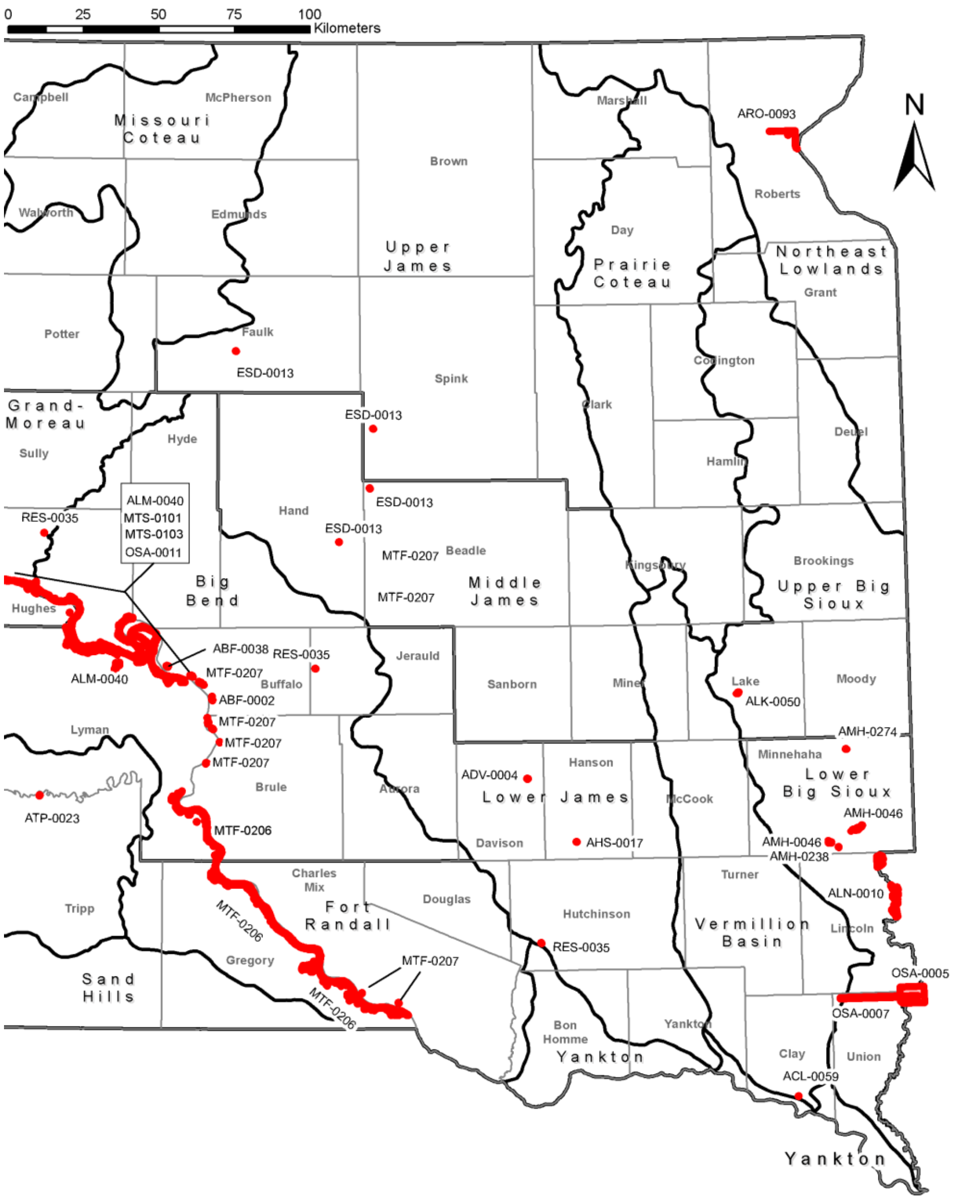


Figure 3. Eastern South Dakota showing locations of reports and publications discussed in text.

KEY to ARMS Archive Numbers

ABF-0003	Zimmerman et al. 1981
ABF-0038	Ahler and Toom 1989
ACL-0059	Mandel 1992
ADV-0004	White 1987b
AHS-0015	Mandel 1994
AHS-0017	Fosha et al. 1994
ALK-0050	Donohue and Davis 2003
ALM-0040	Toom et al. 1989
ALN-0010	White 1988b
ALN-0011	White 1988a
ALN-0204	McClelland 2009
AMH-0046	White 1987a
AMH-0238	Hannus et al. 1991
AMH-0274	Buhta 2009
ARO-0093	Messerli and Donohue2005
ATP-0023	Donohue 2001
ESD-0013	Haug et al. 1983
MTF-0206	Mandel and Brown 1985
MTF-0207	Tibesar et al. 1986
MTS-0101	Toom and Steinacher 1980
MTS-0103	Picha and Toom 1984
OSA-0005	Artz and Riley 2006
OSA-0006	Artz and Krieg 2007
OSA-0007	Artz and Riley 2010
OSA-0011	Toom 1992
RES-0035	Abbott 1992

PART II. GEOARCHAEOLOGICAL OVERVIEW

Statewide Geological Overview

This section begins with a statewide overview of South Dakota's bedrock and glacial geology. Although often far pre-dating the arrival of humans in the western hemisphere, these geological deposits define the landscapes on which human occupation took place. The second part of this section introduces the Holocene geology of the state. Emphasis is placed on identifying the major lithologies (e.g., alluvium, colluvium, eolian silts) that comprise Holocene deposits in the state, and introducing the stratigraphic frameworks that can be used to subdivide vertical and lateral sequences of sediments into stratigraphic units. Stratigraphic units are formally (e.g., North American Commission on Stratigraphic Nomenclature 2004) referred to as "lithostratigraphic units," a recognition of the fact that each stratum in the geologic record is comprised of rocks and sediments of similar lithology. Lithostratigraphic units can be traced and mapped across large areas. Generally speaking, it is the distribution of lithostratigraphic units that are depicted on geologic (e.g., Martin et al. 2004) maps. Soils mapped by the Natural Resources Conservation Service (NRCS; Soil Survey Staff 1993) can also be identified to a specific lithologic parent material (e.g., shale, schist, alluvium), but are often difficult to correlate with lithostratigraphic units.

GEOLOGY, GEOMORPHOLOGY, AND ARCHAEOLOGICAL REGIONS

The geomorphology and surficial geology of South Dakota are varied and complex, but in general, fit well with the archaeological regions defined by Winham and Hannus (1990). The Missouri River divides the state into two halves, colloquially referred to as "East River" and "West River." In regions east of the river, the surficial geology is comprised of Pleistocene glacial deposits. West of the river, bedrock dominates the landscape. The White River Badlands, Lower White, and Sand Hills regions are underlain by Tertiary silts, sandstones, and clays. The Black Hills has a Precambrian core of igneous and metamorphic rocks, ringed by Paleozoic, Triassic, and Jurassic limestones, sandstones, shales, and clays. In the Sandstone Buttes and Grand Moreau Tablelands, Cretaceous sandstones and shales are exposed at the surface, with limestone capping butte tops. Tertiary bedrock is also exposed in parts of these two regions (Gries 1996).

East River regions correspond to greater or lesser degrees with major glacial advances into the state. Pre-Wisconsin glaciers extended westward to and slightly beyond the Missouri River. Between 20,000 and 14,000 years ago, the late Wisconsinan James Lobe advanced southward, in an area coinciding with the Upper, Middle, and Lower James regions (Clayton and Moran 1982).

The Prairie Coteau Region, and parts of the Upper and Lower Big Sioux regions, escaped Late Wisconsinan glaciation. At the north tip of the Prairie Coteau, the glacier split into two lobes, the James Lobe advancing south through what became the James River valley, and the Des Moines lobe advancing to the southeast into Iowa (Clayton and Moran 1982). The terrain between the two lobes is underlain by older Wisconsinan and Illinoian glacial deposits (Gilbertson 1989; Gries 1996).

A final advance into the state came about 11,700 B.P., as the Red River lobe advanced down the valley of the same name in North Dakota. The edge of this glacier corresponds roughly to the western edge of the Northeast Lowlands region. This moraine blocked the drainage of rivers running south along the ice-front, forming Lake Dakota, a ca. 30-mi-wide body of water in the Upper James Region.

The Big Sioux, Vermillion, James, and Missouri rivers carried outwash from the late Wisconsinan glaciers. The Missouri was a major conduit for meltwater from the northern Plains, leading to its deep entrenchment into the pre-glacial landscape (Clayton and Moran 1982; Coogan 1987).

Throughout the state, streams have incised valleys into the surficial rock units, and the valleys contain alluvial fills deposited by the rivers through time. The alluvial fills are primarily Pleistocene and Holocene in age. The Holocene fills, with the potential to contain buried archaeological sites, typically underlie the lowest surfaces in the valleys, and are topographically lower and laterally inset against, the older Pleistocene surfaces. Both the Holocene- and Pleistocene-age surfaces can comprise multiple, stepped levels. These terraces represent former floodplains of the streams.

Eolian (windblown) deposits are widespread west of the river, and are present but less extensive in the East River regions. Dunes of eolian sand dominate the landscape of the Sand Hills Region. Dune fields occur elsewhere in the state, but outside the Sand Hills, are typically silty-textured. The eolian silts, sometimes called loess, often mantle the landscape in sheets of relatively constant thickness, rather than dunes. Eolian sands and silts are found on both uplands and terraces. Much of the eolian sediment was deposited during the terminal Wisconsinan and Holocene, and is known to contain buried archaeological sites, especially west of the Missouri River. Evidence from the Nebraska Sand Hills suggests that, despite their great thickness, the dunes of this region are primarily Holocene in age (Ahlbrandt et al. 1983). Older, Pleistocene eolian deposits have been identified, such as the Red Dog Loess in the White River Badlands region (Donohue 2001, Donohue and Hanenberger 2001; Rawlings et al. 2003). East of the Missouri River, deposits of late Pleistocene and Holocene loess have been noted as thin veneers on till plains and glacial lake plains in the Coteau uplands (Flint 1955: 128). These wind-blown sediments of silts and fine sands probably derived from local outwash deposits (Flint 1955:164; cited by Messerli and Donohue 2005).

INTERREGIONAL PATTERNS

A statewide but generalized perspective on buried site potential can be obtained from the 1:500,000 surficial geology map of South Dakota (Martin et al. 2004). Most of the mapping units are bedrock formations or glacial deposits underlying uplands. Seven mapping units refer to sedimentary environments that are important from the perspective of buried site potential. Their distribution is shown in Figures 4-5. The map units and their symbols (prefaced with “Q” for Quaternary) are as follows:

- Quaternary alluvium (Qal)
- Quaternary eolian (Qe)
- Quaternary delta (Qd)
- Quaternary lacustrine (Qll)
- Quaternary landslide (Ql)
- Quaternary outwash (various units beginning with Qo)
- Quaternary terrace (Qt)
- A colluvium unit (Qc) is also mapped by Martin et al. (2004), but is not considered in this analysis. It only occurs in small areas on Black Hills mountain sides and is described as “clay to boulder sized clasts forming rubble residuum and talus” (Martin et al. 2004).

At a 1:500,000 scale, these sedimentary environments cannot be mapped in detail. Only the largest contiguous areas can be shown. Nevertheless, a generalized overview of their distribution among archaeological regions is of use. For example, areas mapped as Quaternary alluvium comprise the river valleys where the widest and thickest sequences of Holocene alluvium can be expected, and where buried sites can be the most difficult to find because of the volume of sediment that is present.

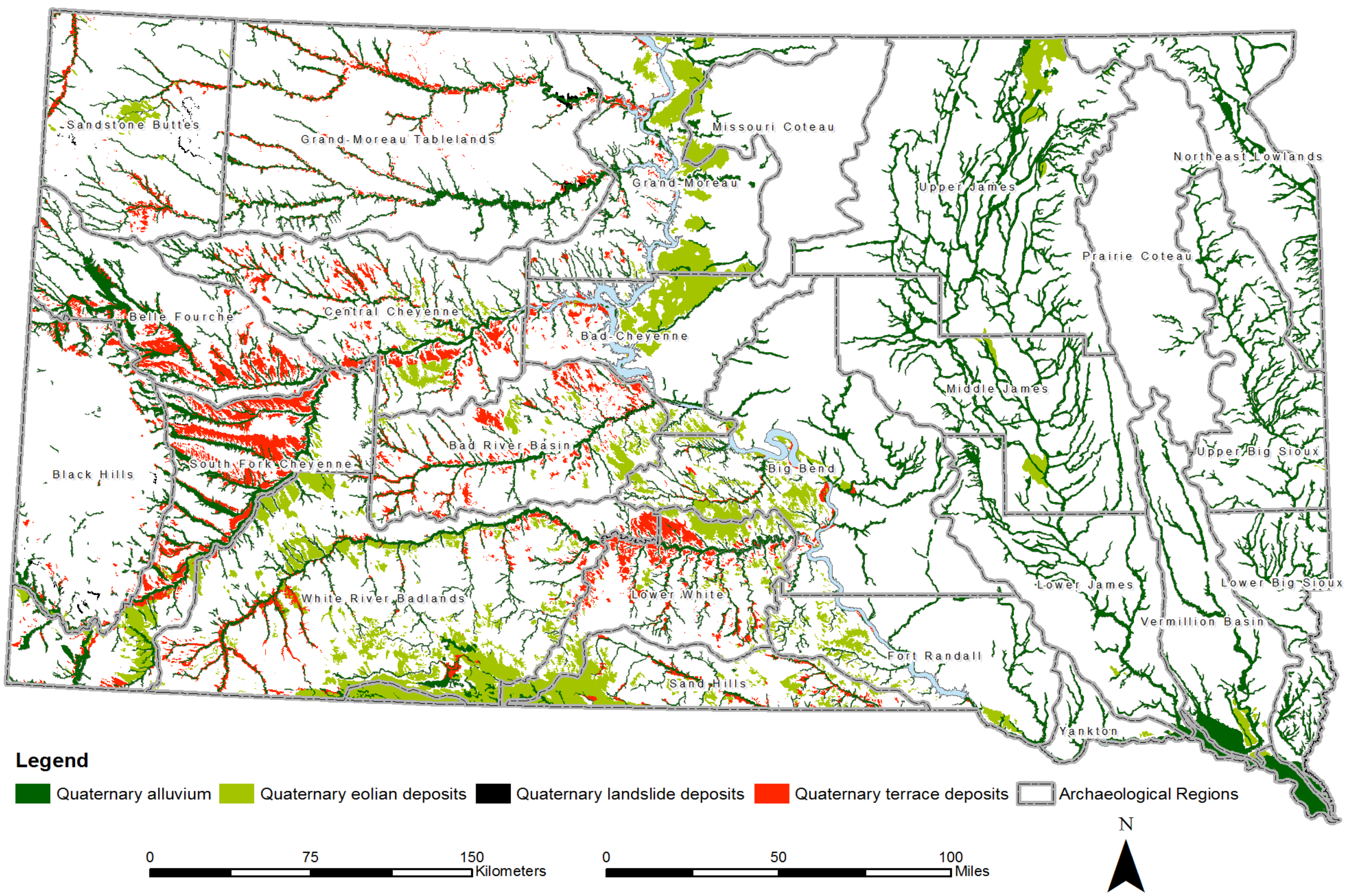


Figure 4. Quaternary map units of South Dakota extracted from Martin et al. (2004).

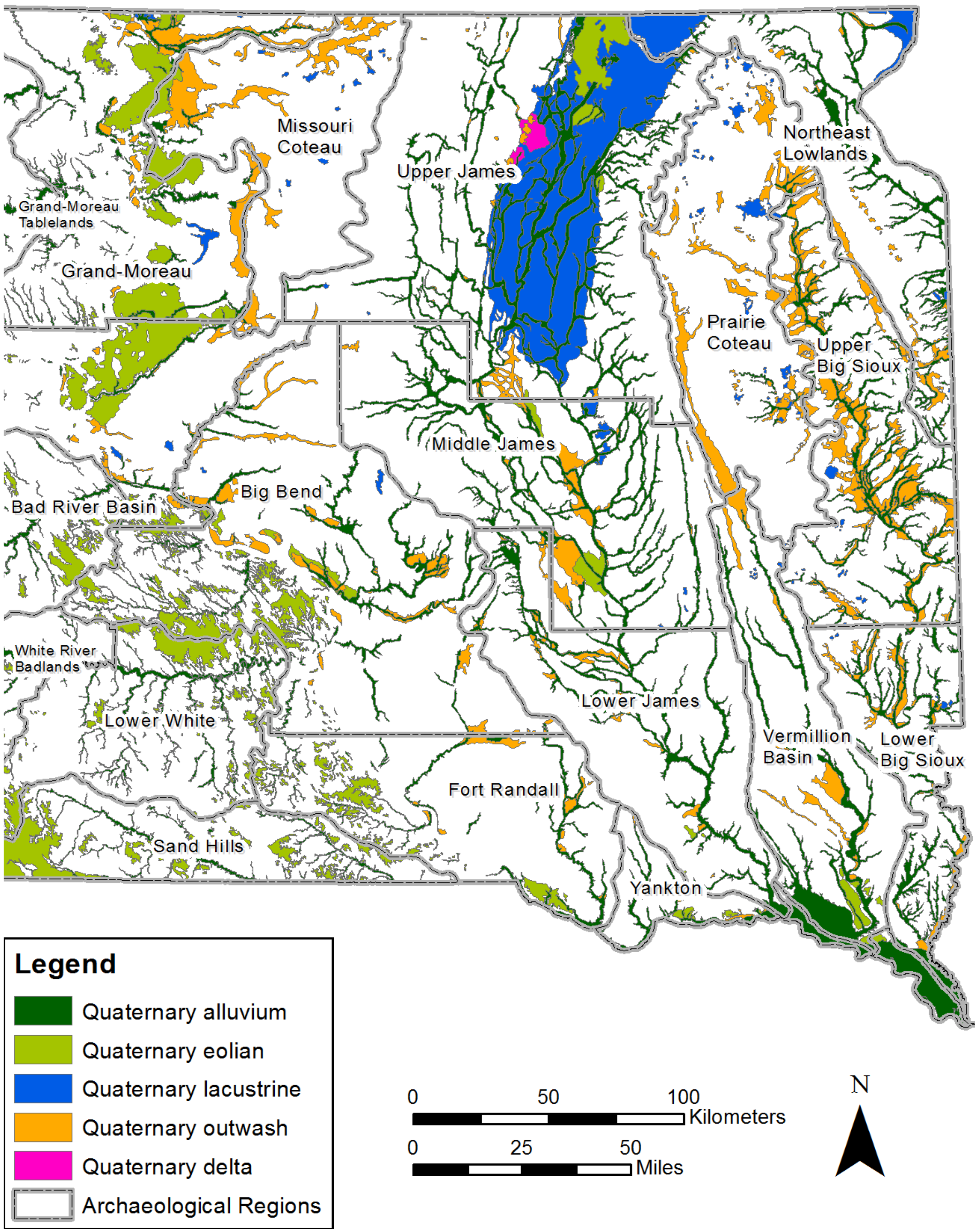


Figure 5. Quaternary map units in the glaciated regions of eastern South Dakota extracted from Martin et al. (2004).

Quaternary Alluvium

ArcGIS was used to calculate the total area of the Qal map unit in each archaeological region (Figure 6; Table 3). The mapped valleys comprise 8-12% of the total area of West River, East River, and Missouri Trench regions, but are less extensive in the Prairie and Missouri Coteau regions, where glaciated topography creates closed drainage systems. Little Quaternary alluvium is mapped in the Black Hills, where streams flow in narrow mountain valleys and canyons that are too small to be mapped at 1:500,000. In the Sandstone Buttes and Grand-Moreau Tablelands, the Qal map units do not penetrate as far into the uplands as do those in other West River archaeological regions. This reflects the presence in these regions of relatively broad, undissected tablelands, but also that the upper reaches of the drainage network are often deeply dissected, creating a rugged topography of steep narrow valleys that cannot be individually mapped at 1:500,000.

Quaternary Terraces

Much of the area mapped as Quaternary terraces (Qt) by Martin et al. (2004) is comprised of Pleistocene and older surfaces that flank large rivers west of the Missouri River. A relatively small percentage of the Qt map units consist of lower terraces, closer in elevation to the valley floors. Most, however, are situated tens of meters above the latest Wisconsinan and Holocene-age valley floors. The geoarchaeology of sites associated with these terraces is discussed by Brakenridge and McReady (2008), Coogan (1987), Fosha (1992), Hajic (2008) and McFaul (2010), among others. For all intents and purposes, these very high terraces lack buried site potential and can be so considered for purposes of archaeological survey and evaluation.

In East River South Dakota, Quaternary terraces are underlain by glaciofluvial outwash, mapped as Qo by Matyin et al. (2004) The outwash deposits are primarily late Wisconsinan in age, with a few remnants of pre-Wisconsinan outwash on the Prairie Coteau (Martin et al. 2004). The outwash terraces are underlain by deposits of sands and gravel laid down by high-energy melt water floods and typically stand at elevations above the reach of Holocene flooding. These terraces typically lack buried site potential as long as they stand high enough to have escaped overbank deposition during the Holocene.

Quaternary Eolian

The eolian deposits mapped by Martin et al. (2004) are most extensive in the Sand Hills Region; proximal to the Missouri Trench; along the South Fork Cheyenne and Cheyenne rivers; in the vicinity of the Cave Hills in the Sandstone Buttes Region; and in a portion of the Lake Dakota lake plain in the Upper James Region. The map unit covers 5% of the state, but is surely an underestimate. Not mapped by Martin et al. (2004) are the extensive sand and loess sheets that are found on uplands throughout western South Dakota outside the Black Hills.

Quaternary Lacustrine

The Quaternary Lacustrine map unit includes the larger glacial lakes in the glaciated eastern part of the state, as well as the former bed of Lake Dakota. This lake bed comprises 21% of the Upper James archaeological region. Lacustrine landforms are also extensive in the glaciated terrains of the Missouri and Prairie Coteau. The area mapped as Qll in the extreme northeast corner of the state is the southern extent of glacial Lake Agassiz, and includes the outlet through which it drained into the Minnesota River.

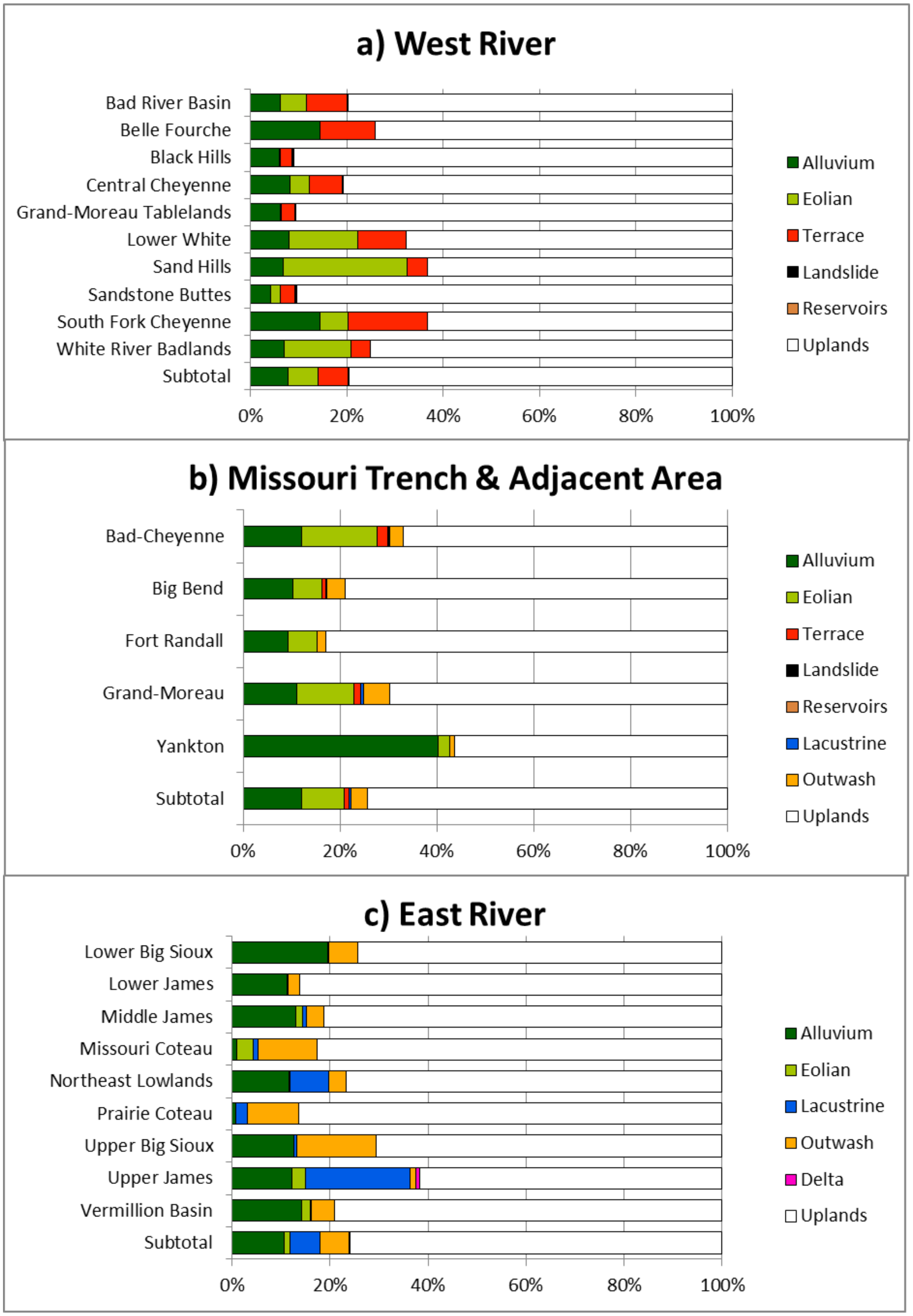


Figure 6. Distribution of Quaternary map units (Martin et al. 2004) among archaeological regions.

Table 3. Area (ha) of Geological Mapping Units (Martin et al. 2004) among Archaeological Regions.

Archaeological Region	Uplands	Allu-vium*	Eolian	Terrace	Land-slide	Lacu-strine	Out-wash	Delta	Total
West River									
Bad River Basin	604,441	47,727	39,888	65,173	743		16		757,989
Belle Fourche	480,121	93,826		73,676					647,623
Black Hills	813,811	53,735	1,321	22,610	3,093				894,569
Central Cheyenne	758,348	78,461	36,602	64,811					938,222
Grand-Moreau Tablelands	1,585,767	109,983	1,301	49,745	4,527		4		1,751,326
Lower White	398,686	46,650	84,229	59,557					589,122
Sand Hills	291,337	31,135	118,219	19,446					460,137
Sandstone Buttes	797,340	36,837	17,573	26,568	3,361				881,679
South Fork Cheyenne	565,956	129,139	52,384	146,486	285				894,251
White River Badlands	1,284,687	118,613	236,938	69,140	570				1,709,948
Total	7,580,493	746,105	588,456	597,212	12,579	0	20	0	9,524,866
Percent	79.6%	7.8%	6.2%	6.3%	0.1%	0.0%	0.0%	0.0%	
Missouri Trench*									
Bad-Cheyenne	388,169	69,957	89,715	13,257	715	1,709	15,665		579,186
Big Bend	1,028,001	134,138	77,789	11,015		1,765	50,397		1,303,106
Fort Randall	534,049	59,859	38,031	737			10,872		643,547
Grand-Moreau	640,751	101,662	108,373	12,037		6,131	49,075		918,029
Yankton	102,935	73,232	4,660				1,607		182,433
Total	2,693,904	438,847	318,568	37,046	715	9,605	127,616	0	3,626,301
Percent	74.3%	12.1%	8.8%	1.0%	0.0%	0.3%	3.5%	0.0%	
East River									
Lower Big Sioux	289,311	75,703	20			999	22,692		388,725
Lower James	635,833	82,884	1,147				17,378		737,242
Middle James	762,802	121,393	13,976			6,664	34,425		939,260
Missouri Coteau	489,200	5,545	20,316			5,722	71,234		592,017
Northeast Lowlands	452,694	68,863	327			47,236	20,748		589,868
Prairie Coteau	643,171	6,032				16,592	78,518		744,313
Upper Big Sioux	492,905	88,058	518			4,290	113,254		699,026
Upper James	959,652	188,771	43,138			333,024	19,115	10,883	1,554,584
Vermillion Basin	460,008	82,341	10,439			820	27,330		580,937
Total	5,185,576	719,590	89,881	0	0	415,348	404,694	10,883	6,825,972
Percent	76.0%	10.5%	1.3%	0.0%	0.0%	6.1%	5.9%	0.2%	
Grand Total	15,459,974	1,904,542	996,905	634,258	13,294	424,953	532,329	10,883	19,977,139
Percent	77.4%	9.5%	5.0%	3.2%	0.1%	2.1%	2.7%	0.1%	

* The Alluvium map unit for the Missouri Trench regions includes the surface area of Lakes Oahe, Sharpe, and Francis Case, which inundate much of the former alluvial valley of the Missouri River in South Dakota.

Quaternary Landslide

The landslide deposits mapped by Martin et al. (2004) are described by them as "landslide, slump, and collapsed material composed of chaotically mixed boulders and finer grained rock debris [with thicknesses] up to 180 ft (55 m)." These deposits are mapped mostly in the Black Hills and in steeply dissected areas of the Grand Moreau Tablelands and Sandstone Buttes
regions. These are areas where a combination of steep slopes and erodible bedrock create the highest risk of mass wasting, with contiguous areas large enough to be mapped at 1:500,000. As previously discussed, these processes are active at smaller spatial extents throughout western North Dakota, and to a lesser extent east of the river.

HOLOCENE GEOLOGY AND GEOARCHAEOLOGY

Prior to the 1950s, little was known about the Holocene geology of the Northern Plains (Artz 2000). Sheldon (1905) reported hearths in the White River badlands, exposed in stream banks, and buried 2.4-3 m below the surface. In the early 1930s, W. H. Over discovered prehistoric ceramics in the A horizon of a soil buried 0.5-2.5 m below the surface of Missouri River terraces north of Pierre. He referred to this manifestation as the "Old Soil Zone Culture" (Sigstad and Sigstad 1973-318-322; Wedel 1977). Also in the 1930s, collaboration between an archaeologist and a geologist resulted in assigning a terminal Wisconsinan age to a human burial and associated lanceolate points at Browns Valley, Minnesota, located just across the state line from northeastern South Dakota (Jenks 1937; Leverett 1932). A late Paleoindian affiliation was confirmed by a radiocarbon age of 9094+/-82 BP on human bone from the site (Shane 1991).

The first intensive interdisciplinary collaboration between geologists and archaeologists occurred as part of the Smithsonian Institution's River Basin Surveys (RBS) in the middle decades of the 20th century. The Ray Long site, in the Angostura reservoir in southwest South Dakota (Hannus et al. 1986), and the Medicine Crow site in the Big Bend of the Missouri River (Ahler and Toom 1989) were among the preceramic sites discovered and investigated by the RBS (Wheeler 1955; White and Hughes n.d.). Also part of the RBS, Coogan and Irving (1959) mapped and described the terraces of the Missouri River, establishing the "MT" terrace sequence still used today in the Trench. Importantly, they demonstrated that the windblown silts mantling the MT-1 and MT-2 terraces were Holocene in age. Coogan (1960) also extended the MT sequence into the lower reaches of Soldier Creek, a Missouri River tributary in Buffalo County.

Since the 1960s, knowledge about the Holocene geologic history of South Dakota has grown, but has rarely been drawn together into regional syntheses like that produced by Coogan (1987) for the Missouri River trench, or for the White River by White and Hannus (1985). However, both eolian and alluvial stratigraphic units in South Dakota have been correlated with stratigraphic sequences in neighboring states.

Oahe Formation

Eolian silts that mantle uplands and Pleistocene terraces in much of western South Dakota are correlated with the Oahe Formation, first defined in western North Dakota by Clayton et al. (1976). The Oahe Formation has five members, the Mallard Island (late Wisconsinan), Aggie Brown (terminal Wisconsinan and early Holocene), Pick City (middle Holocene), and Riverdale (late Holocene). Of great importance in the Oahe Formation is the presence of buried soils, the dark-colored A horizons of which provide excellent stratigraphic markers for recognizing member contacts, and correlating widely-separated exposures. The paleosols occur in the Aggie Brown and Riverdale members, and are referred to as the Leonard and Thompson paleosols, respectively (Clayton et al. 1976). Alluvial units that correlate with the Oahe Formation are also recognized (Artz 1995), including the Leonard paleosol (Artz and Ahler 1989; Van Nest 1985).

Donohue and Hannenberger (2001) note the identification of Oahe Formation sediments at sites in Dewey, Custer, Potter, Buffalo, Tripp, and Melette counties. It is present on terraces of the Missouri Trench (Coogan 1987) and in the White River badlands (Kuehn 2003). Its presence is poorly known in the East River portions of both Dakotas.

DeForest Formation

The DeForest Formation is a stratigraphic sequence defined for Holocene valley alluvium in Iowa and eastern Nebraska (Bettis 1990; Bettis and Mandel 2000). Alluvial stratigraphy in southeastern South Dakota in the James, Vermillion, and Big Sioux river drainages closely resembles and undoubtedly correlates with sediments of the DeForest Formation (Artz and Riley 2006; James Donohue and Michael Kolb, personal communication 2011). The DeForest Formation has several members. The Gunder, Roberts Creek, and Camp Creek members are early-middle Holocene, late Holocene, and historic in age, respectively, and are comprised of alluvial sediments. The Corrington Member is early-middle Holocene in age, and underlies the surface of alluvial fans. The Honey Creek Member, a late Holocene unit, has been defined in eastern Nebraska by Dillon and Mandel (2005), but has not yet been widely traced in adjacent states. The DeForest Formation members are differentiated primarily by color, texture, sedimentary bedding, and soil horizonation (Bettis 1990).

The northern extent of the DeForest Formation is not known but probably does not extend to the state's northern border. The James River alluvial sequences described by Picha and Gregg (1985) in southeastern North Dakota are more complexly stratified than the usually homogenous DeForest Formation, and therefore represent a different, and as yet not formally named stratigraphic unit. Alluvial sediments in the Missouri Trench do not resemble the DeForest Formation, nor do those west of the river.

Northwestern Plains Alluvial Sequences

A number of alluvial terrace sequences have been defined for the northwestern Plains (Albanese and Wilson 1974; Haynes 1968; Leopold and Miller 1954). Albanese (1998) extended these to western South Dakota, basing his discussion on a sequence of five units, A-E, originally defined by Haynes (1968) for a much larger area of the western United States. As summarized by Hajic (2008:9-10), Units A and B formed between about 14,000 and 8500 B.P., and contain many of the region's known Paleoindian sites. Unit C was deposited between 7500 and 5500 BP, and is separated from Units A-B by an erosion surface that represents a ca. 1000 year gap in the sedimentary record, and in some areas, such as the Powder River Basin, is missing entirely. Unit D is primarily a colluvial unit that was deposited between 5000 and 1200 B.P., and often contains Middle and Late Plains Archaic sites. Unit E was deposited after 1000 B.P., following a period of regional stream entrenchment between 1200 and 1000 B.P. Albanese (1998) suggests that this entrenchment resulted in the formation of three alluvial terraces, correlated with the Kaycee, Moorcroft, and Lighting terraces defined by Leopold and Miller (1954).

GEOLOGICAL PROCESSES

Identifying and evaluating buried site potential requires an understanding of the geological processes that are at work in the landscape. Prehistoric people focused on specific locations, and often specific landforms in deciding where to live or carry out non-habitation tasks. Consequently, identifying and evaluating buried sites requires an understanding of geological processes that work at a scale similar to that of an archaeological site or site cluster.

Generally speaking, the processes that shape the Holocene geologic record can be grouped under the headings of deposition, erosion, and weathering. Landscapes are mosaics of sedimentary environments, each characterized by different combinations of processes. Sedimentary (or depositional) environments are so fundamental to landscape evolution that they are usually used to organize broad overviews of geologic and geomorphic processes (e.g., Ferring 1992; Nichols 1990; Reineck and Singh 1995; Waters 1992).

In addition to its primary role as a record of past cultures, the archaeological record also provides evidence for the processes that have been active in laying down the sedimentary matrix within which archaeological deposits are found. Regardless of a site's age, or the name given to the strata within which it occurs, the site's geological context cannot be interpreted without applying an understanding of geological process.

Each sedimentary environment sets different conditions for buried site potential, including not only the burial of archaeological deposits, but also their preservation from subsequent erosion. Therefore, landforms that comprise the landscapes of South Dakota can be evaluated in terms of their potential for the burial and erosion of archaeological deposits.

In any site or survey area (APE), landscape processes can be inferred from the evidence of geomorphic factors such as slope, hydrology, and erodibility of available geologic materials. Landscape processes can also be identified in data obtained by subsurface testing, including lithology (sediments), pedology (soil horizons), stratigraphic contacts, and relative or absolute age. Stratigraphy, defined as vertical and horizontal relationships of strata identified in the subsurface, provides data on changes through time and across space in geologic processes that could act to erode or bury archaeological deposits.

The term "potential" is widely used in archaeology, most often to express the likelihood that sites will be found at a given location. Stream terraces, hill tops with extensive views, stream confluences, and rock shelters are kinds of settings considered to have higher potential than steep, eroded slopes, and land far from water sources. The term can be used qualitatively, based on an individual archaeologist's "feel" for where sites are found. Site potential can also be modeled quantitatively, and used to generate statistical probabilities of site occurrence (Minnesota Department of Transportation 2005, Kvamme 1992; Mehrer and Wescott 2006; Van Leusen and Kamermans 2005).

"Potential" is used differently in geoarchaeology. Initially, Midwestern and Plains geoarchaeologists considered potential to be primarily a function of the age of the sediments. Sediments had archaeological potential if they were deposited within the known span of human occupation in North America (e.g., Thompson and Bettis 1980; Bettis and Benn 1984). However, much Holocene alluvium consists of thick, basal packages of sands and gravels deposited in active stream channels that would not have been habitable. There has been increasing awareness that potential is not just a factor of age, but also of habitability and post-occupation preservation. For example, higher, better drained landforms such as levees, alluvial fans, and colluvial slopes are more likely to have archaeological sites than lower, flood-prone, abandoned channels and flood basins (Artz 1996). These landforms reflect different processes and rates of sediment deposition and erosion. Through subsurface coring or trenching, spatial, and temporal changes can be observed in processes such as deposition, erosion, soil formation, and geochemical weathering.

Soil formation can provide important information about drainage, geomorphic stability, and therefore habitability of landforms (Mandel and Bettis 2001). The most habitable surfaces often have more well developed soil structure, and brown, yellow, and red soil colors, relative to the gleyed (gray and olive colors) soils of poorly drained surfaces (Bettis 1992).

This study focuses on buried site potential which can be inferred from geomorphological and stratigraphic data obtained by archaeological and geoarchaeological investigations. These data can be used to determine the potential for buried archaeological deposits to be present, and to evaluate the integrity of deposits that are encountered. Eigenberger et al. (2009) provide a useful approach to evaluating buried site potential. Their categories are quoted here, and discussed extensively in a subsequent section, Concepts and Considerations, below.

> "High Potential: depositional processes are…conducive to preserving buried archaeological deposits in primary context and have the potential for separation of archaeological components.
>
> "Moderate Potential: depositional processes … are conducive to preserving buried archaeological deposits but with possible physical modifications to the primary context [i.e., eroded or otherwise disturbed].
>
> "Low Potential: deposits... are too old or too thin to contain buried archaeological deposits in primary contexts or… accumulated in high-energy depositional environments (fluvial channels, for example) where archaeological deposits would not survive in primary context" (Eigenberger et al. 2009:3-3).

These definitions have the advantage of being based primarily on geological processes as they relate to habitability and post-occupational preservation of landforms. The same general concepts are used by geoarchaeologists throughout the United States. Indeed, Eigenberger et al. (2009) state that their criteria are based on those of Hudak and Hajic (2008), working in Minnesota, Hajic (2008) working in South Dakota, and Mayer and McFaul (2008), working in Wyoming.

In addition to developing buried site potential criteria, Eigenberger et al. (2009) compiled a useful list of Quaternary sedimentary landscapes and landforms found along the "New Build" section of the proposed DM&E railroad in the South Fork Cheyenne Region (OSA-0004 in Figure 2). For each landform, the dominant depositional processes were identified, along with the landform's buried site potential. Table 4, adapted from Eigenberger et al. (2009: Table 1), expands their approach to include the rest of South Dakota.

As used here, a landscape is a mosaic of landforms. In Table 4, landscapes are grouped into Upland and Stream Valley categories. Landforms in river, creek, and canyon landscapes are primarily late Wisconsinan and Holocene in age, and thus their alluvial, eolian, and colluvial landforms all have some degree of buried site potential. In upland landscapes, landforms vary considerably in the presence, thickness of landforms of Holocene-age landforms and deposits that must be considered in evaluating buried site potential.

Many landforms are present in more than one landscape. Table 5 lists the unique landforms identified in Table 4. Each is briefly defined and discussed below. Detailed information on landforms and geological processes can be found in numerous sources, but that by Waters (1992) is both comprehensive and explicitly geoarchaeological in its perspective.

Eolian Environments

Dunes are comprised of windblown sand that builds to heights of several meters. In the Sand Hills region, dunes can be up to 90 m thick (Martin et al. 2004). The low lying areas between dune crests are called interdunes. Some interdunal areas are deflationary, that is, cleared of dune sand by wind, leaving behind a lag of coarse sand and gravel, often on a bare bedrock surface. Depositional interdunes contain eolian sands deposited by wind, or avalanched down dune slopes. In the Sand Hills, wetlands sometimes form in the interdunal areas, fed by groundwater that percolates down, then laterally, through the dune field. Dunes may advance over these wetlands, burying them. Eigenberger et al. (2009) classified the archaeological potential of dunes as high, probably because of their thickness and Holocene age. However, when active, the windward side of the dunes is subject to deflation, with the sand blowing up and over the crest onto the advancing face of the dune. Thus sites within dunes are sometimes deflated (Waters 1992:195-200). To the author's knowledge, dunes have not been the subject of geoarchaeological investigation in South Dakota.

Table 4. Landforms and Landscapes.

Landscape	Landform / Sedimentary Environment	Dominant Depositional Processes	Buried Site Potential
UPLAND LANDSCAPES			
Uplands, Unglaciated	Unglaciated uplands, shallow to bedrock (tablelands, buttes, hills, ridges, badlands)	predominantly erosional	low
	Cliff dunes	eolian	high
	Dunes	eolian	high
	Rockshelter/caves	rockfall, colluvial	high
	Landslides, slumps	mud/debris flow, landslide, slumping	high to low
	Lip loess	eolian	moderate
	Loess sheet	eolian	moderate
	Low order valleys	fluvial, colluvial	moderate
	Sand sheet	eolian	moderate
High Terrace	Flats	predominantly erosional during Holocene	low
	Dunes	eolian	high
	Playas	lacustrine, eolian	high
	Low order valleys	fluvial, colluvial	high to low
	Loess sheets	eolian	moderate
	Sand sheets	eolian	moderate
	Low order valleys	fluvial, colluvial	moderate to high
Sand Hills	Dunes	eolian	high
	Sand sheets	eolian	moderate
	Interdunal flats	dominant erosional	low
	Interdunal wetlands, lakes	lacustrine, eolian	low
Badlands	Uplands, shallow to bedrock (tablelands, ridges, steep slopes)	predominantly erosional	low
	Colluvial slopes	eolian	high
	Sod tables	eolian, alluvial	high
	Lip loess	eolian	moderate
	Loess sheet	eolian	moderate
	Low order valleys	fluvial, colluvial	moderate
	Landslides, slumps	mud flow, landslide, slumping	high to low
Black Hills	Mountains (various landforms)	predominantly erosional	low
	Alluvial Fans	colluvial, alluvial, mud/debris flow	high
	Canyons	fluvial, colluvial	high
	Rockshelter/Caves	rockfall, colluvial, alluvial	high
	Low order valleys	fluvial, colluvial	moderate
	Landslides, Debris Flow	mud/debris flow, slumping	low
	Talus slopes	debris flow, landslide, slump	low
Uplands, glaciated	Glaciated uplands, shallow to till or glaciofluvial sediment (till plains, moraines, eskers, kames, pothole lakes)	glacial, glaciofluvial, lacustrine	low

Table 4. Landforms and Landscapes.

Landscape	Landform / Sedimentary Environment	Dominant Depositional Processes	Buried Site Potential
	Colluvial slopes	colluvial, mud/debris flow	high
	Dunes	eolian	high
	Low order valleys	fluvial, colluvial	low
STREAM VALLEY LANDSCAPES			
Valley Bottom	Terraces, overbank deposits,	low energy fluvial	high
	channel deposits,	high energy fluvial	low
	floodplain	Historic period vertical and lateral accretion	low (for prehistoric)
Valley Margin	Alluvial fans	alluvial	high
	Colluvial slopes	colluvial	moderate
	Low order valleys	fluvial, colluvial	high to moderate
Lakes, Ponds	Glacial lake plains	lacustrine, alluvial	low to moderate
	Beach ridges	shoreline	moderate
Wisconsinan Terraces	Colluvial slopes	colluvial	high
	Dunes	eolian	high
	Alluvial veneer	low energy fluvial	high (Missouri Trench), high to moderate (East River)
	Low Order Tributaries	fluvial, colluvial	high (Missouri Trench), high to moderate (East River)
	Loess Sheets	eolian	moderate
	Sand Sheets	eolian	moderate
	Outwash terraces, shallow to gravel	glaciofluvial, eolian, fluvial	low

Sand sheets are flat to undulating accumulations of eolian sand that, in South Dakota, form a mantle, usually less than 2 m thick, over relatively level upland flats and ridges. Loess (windblown dust) sheets have the same morphology as sand sheets, and are differentiated only by finer, silty to loamy textures. In reality, mantles of eolian sediment grade from sandy to silty, and are essentially equivalent from the perspective of buried site potential.

Some of South Dakota's most significant archaeological sites are buried in loess or sand sheets, including Jim Pitts (Sellet et al. 2009) in the Black Hills, Ray Long (Hannus et al. 1985) in the South Fork Cheyenne Region, Medicine Crow (Ahler and Toom 1989) and Whistling Elk (Toom 1992) in the Big Bend Region. The Leonard Paleosol has proven to be an important stratigraphic marker for recognizing Paleoindian-aged sediments, and is a factor in the discovery of Paleoindian sites in the eolian mantle (Ahler et al. 1974; Albanese 1985; McFaul 2010).

Cliff dunes and "lip loess" occur at the edge of uplands at bluff edges. As winds carry sediment from valley bottoms, they experience a decrease in velocity as they overtop the bluff, and immediately lose a sizeable share of their sediment load. This results in a thickening of sand and loess sheets at the bluff top (Rawlings et al. 2003; White 1966). Bluff-edge archaeological sites are therefore subject to deeper burial, and increased potential separation of multiple components, then sites farther from the edge. These landforms can occur anywhere an eolian mantle is accumulating on a high tableland, butte, or ridge, primarily west of the Missouri River.

Table 5. Unique Landforms and Sedimentary Environments

Sedimentary Environment	**Landform**	**Processes**
Eolian Environments	Dunes	eolian
	Interdunal wetlands, lakes	lacustrine, eolian
	Interdunal flats, blowouts	wind deflation
	Sand sheets	eolian
	Loess sheets	eolian
	Cliff dunes, lip loess	eolian
	Playas	lacustrine, eolian
Alluvial Environments	Levees, floodbasins, alluvial ridges (top stratum, vertical accretion)	low energy fluvial
	Channels and bars (bottom stratum, lateral accretion)	high energy fluvial
	Terraces	high grading upward to low energy fluvial.
	Floodplain	fluvial vertical accretion
	Terrace veneer	low energy fluvial
	Canyons	fluvial, colluvial
	Low order valleys	fluvial, colluvial
	Sod tables	fluvial, colluvial, eolian
Valley Margin Environments	Colluvial slopes	colluvial, mud/debris flow
	Alluvial fans	fluvial, debris/mud flow
Mass-Wasting Environments	Debris, Mud flows	mud flow, landslide, slumping
	Slumps	mud/debris flow, landslide, slumping
	Talus slopes	mud/debris flow, slumping
Rockshelter/Cave Environments		solution, wind abrasion, rockfall, colluvial, alluvial
Glaciofluvial/Glaciolacustrine	Outwash terraces, shallow to gravel	glaciofluvial, eolian, fluvial
	Glacial lake plains	lacustrine, alluvial, eolian
	Beach ridges	shoreline
	Pothole lakes	lacustrine
Erosion-Dominant Landscapes	Glaciated uplands	hillslope processes, headward incision of streams, mass wasting, eolian deflation; lake bed sedimentation
	Unglaciated uplands	hillslope processes, headward incision of streams, mass wasting, eolian deflation
	Mountains	slope processes, headward incision of streams, mass wasting

Playas are shallow depressions located on high tablelands and flats on nonglaciated uplands. They are shallow, often elliptical in shape, often oriented NW-SE with the prevailing winds, and may pond water, if only seasonally. Little archaeological survey and no geoarchaeological investigation of these landforms has occurred in South Dakota, but elsewhere on the great plains, they are often the location of a rich archaeological record (Labelle et al. 2003). In the Southern Plains, dunes develop on the downside edge of playas, creating a context where archaeological sites can be buried.

Alluvial Environments

Water flowing in streams provides energy for transporting sediment. The size of sediment particles varies with discharge. Fast flowing water has more energy and can move larger particles. The current is swiftest, and therefore sediments are coarser, on the channel bed and on the sand and gravel bars that flank it. As water rises higher and spreads farther from the channel, its velocity decreases, and coarse materials drop out, until eventually the water is carrying only fine sands, silts, and clay. Alluvial environments are therefore divided into high energy environments where sands and gravels accumulate on channel beds and bars, and low energy environments where finer particles are deposited from overbank floods. The high energy environments are unlikely to attract occupation or preserve archaeological deposits, but the low energy environments provide not only habitable surfaces, but the potential for sites to be buried as the floodplain surface slowly aggrades. Terraces, which are former floodplains abandoned by downcutting of the stream, have the additional advantage (from the perspective of site formation and preservation) of being elevated above the active floodplain, and therefore more protected from floods and erosion.

Low-lying terraces, however, can be occasionally inundated by high magnitude overbank floods, resulting in the deposition of a veneer of younger alluvium over the original terrace surface. A terrace veneer is like an eolian mantle in being relatively thin and flat. The soil formed into the terrace fill is sometimes preserved under the veneer. Such veneers may occur on outwash terraces of rivers in the glaciated part of South Dakota.

Investigations of Holocene valley sediments have been conducted throughout the state, including the Big Sioux River (Artz and Riley 2010, Lueck et al. 1988), Highland Creek (Fredlund 1996); the Cheyenne River (Fosha 1992), the Grand River (Brakenridge and McReady 1988), Bear Creek (Harksen 1974), Sage Creek (Kowal 1997; Kuehn 2003), the White River (Hannus and White 1985), and the Missouri River (Coogan 1987; McFaul 1985, 1986).

Low order valleys are small tributaries that are geomorphologically different from larger valleys in being narrower and more steeply graded. Because they are narrow, colluvial transport from the valley walls often has an important contribution to the valley alluvium, to the extent that alluvial (stream transported) and colluvial (slope transported) sediments are intermingled or interfingered with one another in the valley fill. Many low-order valleys have a predominantly erosional history, but others are broad enough to store sediment in terraces. In general, the more V-shaped a valley, the less buried site potential it has. Lower order valleys with U-shaped or flat cross sections have sufficient valley floor space to accommodate the storage of alluvial and colluvial sediment without it being flushed out by flooding of the stream.

When lower order valleys store sediment, buried site potential is high. Wooded draws in the Missouri Trench are known to contain buried archaeological sites (Artz and Toom 1985; Toom and Steinacher 1980). At Lighting Spring (Keyser and Davis 1984), the confluence at one locus of three small valleys resulted in the accumulation of 3 m of sediment in ca. 3500 years, with stratified, Late Prehistoric through Middle Archaic archaeological deposits throughout that thickness. Lange-Ferguson, a Clovis mammoth kill in the Badlands (Hannus 1985) is another example of a highly significant archaeological site buried in small valley alluvium.

Canyons in the Black Hills are different from valleys elsewhere in the state because they are highly constrained in width and depth by resistant bedrock. Steep, impermeable mountain slopes rapidly contribute runoff to streams, resulting in high energy stream flow that can transport large and abundantly available cobbles and boulders, in addition to sands, silts and clays. Relatively thick alluvial fills with highly significant buried archaeological sites are documented in Teepee, Hell, and Gillette canyons of the southern Black Hills (Sellet et al. 2009; Sundstrom 1999; Sundstrom et al. 1999, 2008).

Sod tables occur in the White River Badlands (Kuehn 2003). They are isolated remnants of formerly more extensive valley alluvium or colluvial slopes that have been mostly eaten away by erosion. Archaeological sites are known to be associated with them (Kuehn 2003), sometimes buried and stratified (Winham and Hannus 1991).

Valley Margin Environments

Colluvial slopes are formed of sediment that accumulates at the base of valley walls by the downslope movement of colluvial sediment. Valleys walls are also dissected by steep, lower order valleys, at the mouths of which alluvial fans form. Many colluvial slopes and alluvial fans formed during the Holocene as valley slopes eroded, and small valleys extended headward onto uplands. Colluvial slopes occur as concave-upward aprons along the base of valley walls, while alluvial fans extend as cone-like wedges of sediment from the mouths of tributary valleys.

The texture of the sediments that comprise valley margin landforms is variable. Low intensity precipitation and flood events deposit fine-grained sands, silts or clays on the footslopes and fans. Intense thunderstorms and flash floods can generate sufficient energy to entrain gravel, and even boulders. Fans and footslopes can therefore be complexly stratified, alternating between coarse and fine sediment layers, especially in high relief landscapes, such as those of the Black Hills.

Colluvial processes also function to rework eolian mantles. Coogan (1987) demonstrated that the Oahe Formation is often truncated by erosion, with the sediments transported downslope as colluvium. Indeed eolian and colluvial deposits are sometimes hard to differentiate in upland and Wisconsinan terrace mantles (Albanese 1985; Coogan 1987; Fosha and Albanese 1998). Windblown sediment can be derived from the reworking of local Cretaceous and Tertiary bedrock, as can colluvial sediments. Windblown deposits can also be reworked by local slopewash processes.

Mass-Wasting Environments

Mass-wasting encompasses a variety of processes that result in relatively sudden and often catastrophic failure of steep slopes. Slumps are perhaps the simplest of these, and involve a block of sediment detaching from the top of the slope and slipping down. Mudflows and debris flows require water to saturate and loosen sediment into a viscous slurry that then flows down slope, or via a stream channel. Mudflows occur on slopes cut on fine grained sediments, while debris flows entrain gravel, cobbles, and boulders. Mud- and debris flows are often present in fan and colluvial slope sediments, and contribute to the stratigraphic complexity of these landforms.

Slump blocks can result in the downslope wasting of archaeological sites (Albanese 1999), but can also expose buried archaeological deposits (Fosha 1992; Kuehn 2003). A considerable number of archaeological sites in the White River Badlands Region appear to be contained within slump blocks (Kuehn 2003). Slumping and mudflows are a particularly serious problem along the shores of the Missouri River reservoirs. Mandel (1985) provides an overview of mass wasting processes of slumping along the reservoir shorelines.

Rockshelters and Caves

The buried site potential of rockshelters and caves is demonstrated by the archaeological record from sites such as Beaver Creek Shelter and Capes Cave in the Black Hills, and Ludlow Cave in the Cave Hills (Abbott 1989; Alex 1991; Miller et al. 1993; Over 1936; Weston et al. 1982).). Once formed by solution (in limestone) or fissuring or wind abrasion (in sandstone), rock shelter and caves are subject to filling by roof collapse. In addition, colluvium can wash into the site from adjacent slopes, contributing fine-grained sediment to the fill. Beaver Creek shelter is situated low enough on the bluff that its fill is primarily overbank alluvium that aggraded to a thickness of 3 m prior to 1750 BP after which time the stream cut laterally into the site, removing deposits (Alex 1991).

Glacial Lake Environments

East River landscapes include many glacial lakes and potholes. In terms of Holocene geology, these environments are best known for organic sediment sequences that yield pollen and macrobotanical evidence of late Wisconsinan through Holocene climate change (e.g., Watts and Bright 1968). The lake margins are poorly drained, and archaeological sites are usually found on adjacent uplands. However, lake levels have fluctuated through time. Particularly during the frequent Middle Holocene droughts, lake shore and even lake bed occupations, now inundated, were available for occupation. For example, dredging of the bottom of Five Island Lake in northwestern Iowa encountered faunal remains and associated artifacts dating to an episode of lower lake levels (Benn and Hoppin 2000; Hoppin and Benn 1999)

The lacustrine map unit also identifies the Lake Dakota lake plain in northeastern South Dakota. The archaeological record of this landscape is little known (Donohue, personal communication 2011), but its geoarchaeology may parallel that of Lake Agassiz, a glacial lake of similar age in North Dakota, Minnesota, and Manitoba. The former shores of Lake Agassiz are lined with beach ridges, slightly elevated sand-and-gravel ridges that formed during periods when the elevation of the lake was stable for long periods of time, allowing wave action to create these shoreline features (Clayton et al. 1980). Slightly elevated and well drained, they were often selected for prehistoric occupation, as indicated by regional archaeological surveys along Lake Agassiz (Michlovic 1988). Winham and Hannus (1990) suggest that Lake Dakota beach ridges might be the location of Paleoindian sites.

The Lake Agassiz basin itself is relatively poorly drained and not conducive to prehistoric habitation. The Red River and its major tributaries, however, have formed Holocene-age meander belts within the lake plain. Natural levees within these meander belts, formed during the late Holocene, were elevated, well drained, and attracted prehistoric occupation, with subsequent burial and vertical stratification of archaeological deposits (Michlovic 1988). During the early and middle Holocene, alluvial fans formed along the margins of the lake, and contain multiple buried soils. The buried site potential of these fans is indicated by the Rustad site, a stratified, multicomponent, Early Archaic bison processing site (Michlovic and Running 2005).

The Rustad site is also associated with a delta of Lake Agassiz. Deltas formed when the lake level was high. Sediment, discharged into the lake by rivers, spread out across the lake bed beneath the water surface. As the lake drained, the deltas were left as higher surfaces raised above the lake bed. One such delta is mapped on the west shore of Lake Dakota by Martin et al. (2004).

Erosion-Dominated Landforms

Although sedimentary environments with buried site potential are extensive in South Dakota, most of the land area is comprised of uplands where bedrock or glacial deposits older than human prehistory are at or near the surface. The Holocene record on such landforms is primarily one of erosion. Hillslope processes such as sheetwash and mass wasting erode slopes, and stream valleys extend their upper reaches into the uplands by fluvial processes of headward incision. Archaeological sites in these areas are at or near the surface, and buried site potential is very low.

Regional Overviews

This section reviews reports and other publications identified by the ARMS bibliographic search described under “Information Sources,” above. The summaries are brief, and are intended primarily to guide readers to studies that contain useful geoarchaeological data. The discussion is organized by archaeological regions, grouped into West River, Missouri Trench, and East River sections. Some deal with large study areas, providing information on subregional patterns of Holocene geology and stratigraphy. Others are site-specific, focusing on the smaller spatial extent of individual sites or groups of sites. In general, more detail is given for sources from the East River archaeological regions, where relatively little geoarchaeology-specific work has been done, than the West River and Missouri Trench regions, where much more such work has been done.

WEST RIVER

The search identified no studies from the Belle Fourche, Lower White, or Sand Hills regions.

Black Hills

Sundstrom (1999) provides an overview of landforms and sediment sequences in the Tepee and Hell canyon areas of the southern Black Hills. She evaluates the potential for buried deposits, and for site preservation in uplands, colluvial slopes, alluvial fans, and canyon-bottom alluvium. Fredlund (1996) provides a similarly detailed geological sequence for a stream valley in Wind Cave National Park, also in the southern Hills.

Research designs for mitigative excavations of sites in Custer and Meade counties (Donohue 1992; Hanenberger et al. 1993) are good examples of using detailed knowledge of the geological context of sites, gathered from previous excavations, to design an excavation strategy that maximizes data recovery from buried deposits. Subsequent work at these and other sites (Donohue et al. 1996; Smith et al. 1994; Sundstrom et al. 1999, 2002, 2008; Sellet et al. 2009) provide the basis for a regional understanding of valley alluvium and colluvium in terrace, fan, and footslope settings on the Black Hills.

Interdisciplinary studies of archaeological and geological stratigraphy were conducted at Beaver Creek Shelter (Abbot 1989; Alex 1991; Miller et al. 1993) and Capes Cave (Weston et al. 1982), both in the southern Black Hills. Beaver Creek Shelter is a particularly complex setting because it is located at the same elevation as the Beaver Creek valley floor. The primary depositional vector has therefore been alluvial, rather than rockfall, roof spalling, and colluvial processes. Two episodes of filling, separated by an erosional episode, are documented in the shelter deposits (Miller et al. 1993).

Sinkholes are a sedimentary environment that in South Dakota are unique to the Black Hills, where soluble bedrock is subject to karst-like collapse processes. At Vore site, in the Red Valley in the Wyoming part of the Black Hills, Late Prehistoric people drove bison into a sink formed by the solution of gypsum from bedrock, creating a stratified bison kill (Reher and Frison 1980). Although not an archaeological site, late Quaternary paleontological deposits at Mammoth Hot Springs site (Agenbroad and Mead 1994) are a further indication of the subsurface potential of geohydrological, solutional landforms.

Central Cheyenne

Fosha (1992) provides a detailed overview of the geology and geoarchaeological potential of the Central Cheyenne region landscape, including a synopsis of work by Brakenridge and McReady (1988) in the lower Cheyenne River valley. He describes the geological context of four sites encountered in six study areas: 39HK20, in a thick, eolian deposit with buried soils on a high, MT-4-equivalent terrace; 39HK35, in eolian and colluvial sediments on a terrace at the mouth of a small tributary to the

Cheyenne; 39HK34, apparently buried in clayey, Pierre-Shale-derived colluvium, and contained in a slump block detached from the edge of a high terrace overlooking the Cheyenne River; and 39HK45, a paleontological site comprised of bison bone eroding from alluvial and colluvial slope deposits along a 1 km reach of the narrow valley bottom of a small to the Cheyenne River. The stream valley is deeply incised into an extensive flat on the margin of the breaks that descend to the Cheyenne River valley floor. Although the spatial extent of his study was limited, Fosha (1992) nonetheless documented five different sedimentary contexts in which subsurface archaeological deposits could be found.

Grand-Moreau Tablelands

Hannenberg et al. (2010) conducted large scale excavations at 39DW165, on a highly dissected high terrace above the Moreau River, and 39ZB31, in less dissected uplands at the south edge of the breaks leading to the Moreau River. At both sites buried soils are present within Oahe Formation eolian sediments, including both the late Holocene Thompson and early Holocene Leonard paleosols. At 39ZB31, the Leonard soil is preserved only in swales on the Fox Hills Sandstone bedrock surface where it appears to have been protected from Middle Holocene deflation of the landscape. Preservation of the Leonard paleosol in such low-lying protected landscapes is common in the Dakotas west of the Missouri Trench (Artz 1995).

Sandstone Buttes

Albanese (1985) reported on the geology of three sites on elevated table lands in highly dissected terrain in the vicinity of the North Cave Hills. The Holocene mantle at the sites is 55 to ca. 200 cm thick. On the basis of buried soils, sediment textures, and radiocarbon and artifact ages, this mantle correlates with the Oahe Formation. The Leonard paleosol formed, or is preserved, only in swales on the bedrock surface. Although sediments in similar upland contexts are often considered eolian, Albanese (1985) interprets the mantle as colluvial in origin. Although he does not discuss this interpretation in detail, the implication is that sufficient topographic relief is present that sediment is subject to localized redeposition. Eolian sediments, themselves perhaps locally derived, are subject to this reworking. The processes responsible for reworking of sediments, however, must be relatively low energy, and episodic in nature, or else buried soils would not form or be preserved.

Lighting Spring (39HN204) is located in a valley bottom not far from the sites described by Albanese (1985). The site is located in a basin-like setting at the confluence of three draws that descend from uplands. Between ca. 4000 and 1660 B.P, over 3.3 m of alluvial sediment accumulated at the site, stratigraphically separating 13 occupation levels (Keyser and Davis 1984). Similar sites have not, to the author’s knowledge, been identified in northwestern South Dakota or adjoining North Dakota. A search for geomorphic settings like that of Lighting Spring might lead to the discovery of such sites.

Albanese (1999) documents three bison bone beds, stratigraphically separated in over 3 m of Holocene colluvium at 39HN176. A surface soil and two buried soils indicate that deposition was episodic, over a period of ca. 330 years, as suggested by radiocarbon ages. As part of this report Albanese (1999) also documents the effects of landslides, including rotational slumping and the formation of boulder talus slopes on the landscape and archaeological sites.

Fosha and Albanese (1998) provide a brief report on the Summit Spring site, 39HN569, in the Slim Buttes. At this butte-top site, Late Prehistoric through Early Archaic archaeological deposits are buried in a Holocene sediment mantle that ranges from 15 to 455 cm thick. As at the three North Cave Hills sites (Albanese 1985), the butte-top sediments are identified as “alluvial-colluvial” in origin, suggesting low-energy, nonerosive, and localized movement of sediments through time.

South Fork Cheyenne

Work by Wheeler (1995) at the Ray Long site (39FA65) is one of the earliest examples in South Dakota of the kind of interdisciplinary collaboration that would come to characterize geoarchaeology, with the earth scientist and archaeologists actively working together with explicit attention to the relationship of sediments and stratigraphy to the archaeological deposits. Albanese (1986) and Byrne et al. (1996) describe the site's geomorphic setting and soil stratigraphy. Sedimentary environments include "ephemeral stream alluvium" and valley margin colluvium, which are interfingered in parts of the site (Albanese 1986). The archaeological deposits are buried in a surface mantle that can be correlated with the Oahe Formation on the basis of lithology and buried soils. Characteristic of this formation, weakly developed, A-C profiles are formed in the upper part of the mantle, with a thicker soil, possibly correlative with the Leonard paleosol in the lower part (Albanese 1986; Byrne et al. 1996).

Burnett (2008) and Eigenberger et al. (2009) review the soils, geomorphology, and stratigraphy of the "New-Build" route of the proposed DM & E railroad, which extends a distance of 422 km, roughly paralleling the South Fork Cheyenne from the Wyoming border to Pennington County (Figure 2). Burnett (2008) identifies archaeologically sensitive areas from NRCS-mapped soils, basing his classification on depth to bedrock and parent materials. He states, "Sensitive soils were identified as those that are deeper than NRCS estimates (below 40 to 60 inches), and are derived from alluvium, or eolian sediment (including loess). Shallow soils and those derived from residuum were identified as not sensitive."

Eigengerger et al. (2009) provide a more detailed research design for identifying buried site potential, based on geomorphological mapping and subsurface investigation rather than soil survey maps. The major components of this approach were adopted for the present project.

Hajic (2008) provides a geological overview of the New Build route, along with the results of investigations in 13 study areas along the proposed corridor. These were selected to sample the major landscapes and landforms of the project corridor, including 8 areas in stream valleys of varying sizes, 2 areas on upland playas, 1 area on a loess mantled upland, 1 in an area of landslide deposits, 1 area on shale uplands and 1 area on a high Pleistocene terrace. For each study area, the major landforms were mapped on a base layer of aerial photograph and USGS topographic contours. Subsurface work was conducted with a Giddings drill rig, supplemented with cutbank examination.

White River Badlands

Harksen (1974) identified the stratigraphic context of several prehistoric hearths buried in alluvium of Bear Creek. When considered simply in terms of below-surface depths, radiocarbon ages on the hearths appear to be inverted, with a date of 780±130 RCYBP occurring deeper than one with a date of 2350±180 years RCYBP. The older date is associated with a buried soil that can be traced laterally beneath the terrace surface, and indicates an episode of surface stability and soil formation. According to Harksen (1974), "Sometime between 2350 and 780 years B.P., Bear Creek was rejuvenated and began downcutting. During this period of rejuvenation the stream was entrenched more than 10 feet into its floodplain. After this short period of rejuvenation Bear Creek again became an aggrading stream." Early in this second aggradation episode, the younger hearth was created.

White and Hannus (1985) identify a terrace sequence for the White River, with major depositional episodes at 10,500-5000 BP and 2500-800 BP. Kowal (1997) identified a similar terrace sequence in Sage Creek, a tributary of the White River. She and Kuehn (2003) also discuss an alluvial fan that yielded a radiocarbon age of 2870 RCYBP.

Hannus (1985) describes the stratigraphic sequence at the Clovis-period Lange-Ferguson site. The mammoth kill/butchering site is buried in sediments of a spring-fed pond or bog that was subsequently buried by alluvium. White (1985) details the geomorphology, stratigraphy and soils of the site locality.

One finding was that the stream valley floors are underlain not only by alluvium from the stream itself, but also by alluvial fans that spread from tributary valleys, and coalesce into aprons along the valley margin, extending well out into the valley.

Kuehn (2003) examined landforms and cutbank stratigraphy in several areas of Badlands National Park. He, like Winham and Hannus (1990), calls attention to sod tables as important locations for archaeological sites. These are flat-topped erosional remnants of formerly more extensive valley floors and colluvial slopes. Sediments are well exposed around the edges of the tables, creating good exposures for archaeological deposits. Kuehn (2003) also examined sand sheet and dune deposits on upland and high strath terrace surfaces. Buried soils correlative to the Oahe Formation occur in these deposits. He reviews radiocarbon ages from alluvial contexts (e.g., Kowal 1997).

Rawlings et al. (2003) examined buried soils formed in eolian deposits at the edges of high tablelands in the Badlands, referring to these landforms as "eolian cliff-top deposits." Radiocarbon and optical spin luminescence dating indicate that soils formed in the eolian cliff-top sediments at intervals during the late Holocene. The deposits accumulated on a soil surface that formed in the early Holocene.

Lower White

Donohue (2001) investigated 39TP30, where archaeological deposits are contained in the upper part of a 380-cm-thick Oahe Formation eolian mantle on a terrace ca. 70 m above the White River. Buried soils were present, the uppermost yielding Extended Coalescent artifacts. The age of the lower soils was not determined.

MISSOURI TRENCH

Several studies identified by the search deal with the Missouri Trench as a whole. These include Coogan (1987), Coogan and Irving (1959), and McFaul (1985, 1986).

Bad-Cheyenne

Brakenridge and McReady (1988) mapped the alluvial terraces of the lower Cheyenne River valley in the ca. 50-km-long stretch that is subject to inundation by Lake Oahe. They relate the terrace sequence to the MT terrace system of Coogan (1987). They examined historic channel changes of the river by an examination of early maps. Information about terrace stratigraphy was obtained from lake-eroded cutbanks, at least one of which exposed the Leonard paleosol.

Artz and Toom (1985) focused on areas on the west side of the Missouri Valley, above and below the Lake Oahe dam. They mapped the MT terrace sequence as found in this study area, and described several cutbank exposures of alluvium and eolian sediments. Their archaeological survey encountered buried archaeological sites exposed in cutbanks in the lower reaches of tributaries valleys, surfaces, in eolian deposits on an MT-3 terrace, and in an artificial ditch on the MT-1 terrace. The latter discovery was a human burial.

Big Bend

Coogan (1987; Coogan and Irving 1959, Coogan 1960) did considerable work in the Big Bend region, establishing the terrace sequence and stratigraphy. Detailed descriptions by Coogan and Irving (1959) include ones of MT-2 exposures at the Crow Creek (39BF11) and Medicine Crow (39BF2) sites (Ahler and Toom 1989; and Zimmerman et al. 1981). Irving's work at Medicine Crow was the basis of Ahler and Toom's (1989) detailed discussion of the geological context of pre-Plains Village components at that site.

McFaul (1986), Picha and Toom (1984), Toom (1992), Toom and Steinacher (1980), and Toom et al. (1988) describe the stratigraphic context of 25 archaeological sites on Lakes Sharpe and Francis Case, in

Hughes, Lyman, Stanley, Buffalo, and Brule counties. Most of these are in loess mantles on MT terraces, but some, such as Diamond J (39HU89), are in small tributary valleys.

Toom (1992) defines the Big Bend paleosol, a soil-stratigraphic unit “traceable in MT-2 terrace exposures in the Lake Sharpe area for a distance of over 30 miles.” The uppermost soil in the silt cap on MT-2, it is associated with early Plains Village components in its upper part and Plains Woodland in its lower part.

Toom and Kvamme (2002) employed geophysical remote sensing at the Whistling Elk site (39HU242). The study provided high accuracy images of fortification ditches and houses, including a very large (10 x 10 m) house inferred to have served a ceremonial, communal, or high status residential function.

White, in Zimmerman et al. (1981), provides one of the more detailed stratigraphic descriptions of intra-village deposits, analyzing the complex sequence of natural loess and anthropogenic fills in a fortification ditch at the Crow Creek site.

Fort Randall

Mandel and Brown (1986) outline the MT terrace sequence as represented along the west bank of Lake Francis Case. The MT-1 and MT-2 terraces are mantled by 0.25 to over 10 m of eolian silt which contains buried soils, and therefore is likely to correlate with the Oahe Formation.

Grand-Moreau

This region includes the northernmost part of the Missouri Trench in South Dakota. Toom (1991) summarizes the geological history of this part of the Missouri Trench. McFaul (1986) describes in further detail the MT terrace sequence defined by Coogan and Irving (1959). Sanders et al. (1988) relate the eolian mantle on these terraces to the Oahe Formation. Both Sanders et al. (1988) and Toom (1991) present detailed discussions of the stratigraphy observed at the Travis 2 site (39WW15) on MT-2. Ahler et al. (1974) present similarly detailed discussions for the Walth Bay site (39WW0203).

Coogan (1987) discusses the Walth Bay site in detail, focusing on the high lateral variability of Holocene erosion and deposition evidenced in extensive bank exposures. Multiple erosion episodes occurred during the late Pleistocene and Holocene. Subsequent eolian and colluvial deposition occurred to varying thicknesses over the erosion surfaces. Perhaps the most important conclusion Coogan (1987) drew from his studies is that Holocene stratigraphy throughout the Missouri Trench in the Dakotas is complex, and that preservation of the entire Oahe Formation sequence, as described by Clayton et al. (1976), is an exception for the region as a whole.

EAST RIVER

The search did not identify studies in the Missouri Coteau and Prairie Coteau regions.

Upper, Middle, Lower James River

For a stream with such a central role in East River landscape evolution, the Holocene stratigraphy of the James River valley is virtually unknown. White (1987) conducted a soil coring transect at the Mitchell site (39DV2), an Initial Middle Missouri village located on an outwash terrace on Firesteel Creek. Soil cores profiles indicate an original shallow-to-gravel surface subject to prehistoric cutting to various depths and filling to various thicknesses. Depth to gravel, loamy gravel, or gravelly loam substrate ranges from 12-100 cm.

Mandel (1993) presents the results of backhoe trenching in a small side valley that cuts down through the ca. 30-m-high wall of the deeply entrenched James River valley. Trenches in the center of the valley encountered less than 3 m of alluvial and colluvial sediment that alternated between low-energy silts and clays, and high energy gravels. Gravel content increased with proximity to the valley wall. At the base of the Holocene sediments, atop glaciofluvial outwash was a stratified organic pond deposit. Mandel interpreted the sediments as late Holocene in age, and surmised that early sediments had been eroded from the valley prior to the late Holocene (Mandel 1993; Fosha et al. 1994).

Level I and II surveys for the CENDAK irrigation project (Haug et al. 1983) encountered four buried sites in the Upper and Middle James River in three geomorphic contexts: one in a small draw, two in larger stream valleys, and one on a glacial lake shore. At 39BE115, pottery and bison bone were found in back dirt from a farm pond excavation, and interpreted as a buried site impact by construction. The site is on Turtle Creek, in an outwash valley in the Middle James Region. The Kuhl-Poindexter site (39FK12) is located on a lower terrace of South Fork Snake Creek in the Upper James region. Two meters of alluvium was exposed in cutbanks and test units. A late prehistoric component is near the surface, but Woodland ceramics were encountered at an unspecified depth (Haug et al. 1983:72). At 39SP141, in the Upper James Region, artifacts were found at depths of 80-100 cm in a cutbank on the east edge of Cottonwood Lake. The geomorphology and stratigraphy were not described. At the Majors Gulch site, 39HD30, cultural material was found at depths of 45-80 cm in cutbanks of a narrow valley deeply incised into the Wessington Hills escarpment in the Middle James Region (Haug et al. 1983).

Vermillion Basin/Yankton

Mandel (1992) identified DeForest Formation alluvium at 39CL10, on the Vermillion River upstream from its Missouri River confluence. A cutbank and backhoe trenches exposed a vertically-stacked sequence of the Gunder, Roberts Creek, and Camp Creek members. Two buried soils are formed in the upper and lower parts of the Roberts Creek Member, and a soil is also developed into the upper part of the Gunder Member. Archaeological deposits were present in both the Roberts Creek and Gunder strata. Radiocarbon ages of 3260, 3240, and 3050 RCYBP were recovered from hearths in the upper part of the Gunder Member, and charcoal from the Roberts Creek Member yielded radiocarbon ages of 1850 and 1260 from the lower and upper buried A horizons, respectively. The lithology and ages of the DeForest Formation at the site are very similar to the characteristics of the DeForest Formation in Iowa and eastern Nebraska (Bettis 1990; Mandel and Bettis 2000).

Northeast Lowlands

Messerli and Donohue (2005) describe the stratigraphy at 39RO10 and 39RO117, located on an outwash terrace between the Minnesota River and Lake Traverse. Shovel testing to unspecified depths did not encounter glacial outwash, suggesting that a loamy mantle of some thickness is present on the sites. At 39RO10, mound-like features and adjacent level ground yielded prehistoric habitation evidence, not mortuary remains or features. One of the mounds was underlain by a buried A horizon, and the overburden was interpreted as disturbed topsoil derived from elsewhere on the site. The surface layer, was interpreted as topsoil storage from constructing the nearby highway, or a post-occupation raising of the land surface for an unknown purpose.

The buried soil profile is described in detail, but the geologic processes and origin of the mantle are not discussed. Elsewhere in the report, the authors note that

> "Deposits of Late Pleistocene-Holocene loess (i.e., wind-blown sediments) have been noted as thin veneers atop some lacustrine deposits and near-level areas of glacial till in the Coteau uplands (Flint 1955: 128). These wind-blown sediments of silts and fine sands probably derived from local outwash deposits (Flint 1955:164)" (Messerli and Donohue 2005).

Little is known of these deposits, including their age, source of sediment, thickness, and correlation with regional lithostratigraphic units like the Oahe Formation.

Lower Big Sioux

White (1987) described the sequence of glacial outwash terraces along Skunk Creek, with a "Post-Pleistocene" floodplain inset below the lowest outwash terrace. The floodplain deposits are not described. White (1987) infers them to be less than 1000 years old, based on his interpretation of the NRCS-mapped soils.

On the Big Sioux River at the Blood Run site, White (1988a) identified a Pleistocene age strath terrace, and three Holocene terraces. The highest Holocene terrace includes valley margin alluvial fans.

White (1988b) mapped the surface geology of the Big Sioux River valley northeast of Sioux Falls, identifying four terraces. One is Pleistocene in age, one is underlain by late Wisconsinan outwash, and the lower two are Holocene in age.

Artz and Riley (2006) map the surface geology of two portions of the Big Sioux River valley. In the northernmost of these, three Holocene terraces are present, one early-middle Holocene in age, one late Holocene, and the other historic. The relative ages were confirmed by Giddings cores (Arty and Riley 2006; Artz and Krieg 2007) and backhoe trenches (McClellan 2009) that correlate the alluvium underlying each surface with the Gunder, Roberts Creek, and Camp Creek members of the DeForest Formation. An alluvial fan drapes onto the early-middle Holocene terrace. Its underlying sediments contain buried soils, and are correlated with the Corrington Member. Buried burned layers of possible cultural origin were identified in the cores.

The southern area, downstream from the confluence of the Rock and Big Sioux Rivers, was mapped by Artz and Riley (2006) from aerial photographs, USGS quadrangles, and NRCS soil maps. Much of this part of the valley is a low outwash terrace that is mantled by Holocene-age alluvium. Late Holocene terraces and the historic floodplain are also present. An early-middle Holocene terrace, possibly an alluvial fan, is preserved at the mouth of a small side valley. Alluvial fans are also present along the base of the bluffs of the Rock River.

Artz and Riley (2010) mapped the surface geology of small valleys along a 16 mi transect from the town of Beresford east to the Iowa border. Buried site potential was assigned to valleys based on their size and the presence of NRCS-mapped alluvial soils on the valley bottoms. Valleys without mapped alluvium were considered too narrow to store sediment. Any sediment deposited within them is eventually flushed out by high-energy runoff events. If the NRCS maps alluvial soils in the stream bottoms, these valleys have a sufficiently low down-valley gradient that sediment can accumulate as alluvial fills, although well-defined terrace, floodplains, and colluvial slopes are usually lacking. The largest valleys are sufficient broad that the stream can move laterally over time, creating meander belts, stream terraces, fans, and colluvial slopes of varying ages.

PART III. Developing Guidelines

National Survey of Buried Site Guidelines

A need to identify and evaluate deeply buried sites is, of course, not unique to South Dakota. Most states do not have written standards for buried site testing, but instead, like South Dakota, make decisions on a case-by-case basis. For the present project, 49 documents addressing archaeological survey and testing guidelines were obtained for 35 states, the District of Columbia, and New York City (Figure 7). Most of these were discovered by an on-line search. Additional resources were identified through an email request to the National Association of State Archaeologists listserv **(nasa@list.uiowa.edu).** Replies were received from 14 states: Texas, Oregon, the District of Columbia, Alaska, South Carolina, Pennsylvania, Minnesota, Kansas, New Hampshire, South Dakota, Ohio, Vermont, Arkansas, and Wyoming. Most replies provided Internet links to existing standards. Several referred exclusively to remote (geophysical) sensing in subsurface survey, rather than the geomorphological approach that is the focus of the present project. The posting also generated a brief discussion among several members about the effects of shovel test size, shape, and sampling interval. The interest shown in this topic is indicative of the dominant paradigm in current CRM field methods, in which subsurface testing is focused on relatively shallow excavations.

STATE GUIDELINES

Although probably not a complete list, the 49 documents listed (Table 6) provide insights into variability in national "best practices." Guidelines from six states make no mention of subsurface investigations. Of the other 43 documents, most are concerned primarily with the use of subsurface testing in areas where surface visibility is poor, or in the evaluation of sites identified through surface survey. Thirty six documents acknowledge that, in certain contexts, sites can be buried beyond the reach of shovel tests or other near surface methods. Of these, 11 mention the fact without providing guidance on when, where, and how deep testing should occur, other than a statement that trenching or deep coring may be necessary. Sixteen of the 36 documents provided limited guidance, usually addressing the kinds of landform contexts where sites may be deeply buried, but not providing specifics on methodology. Detailed guidance, including recommended methodologies, trench/core placement and depth, profile recording, and report content, are provided by 9 of the 36 documents.

Table 6 records the kinds of testing methods mentioned in the 43 documents that consider subsurface testing. The "X's" indicate that the method receives mention in the document, regardless of how extensively its use is discussed. Shovel testing is most often mentioned, followed by augering and larger ("formal") test units (e.g., 1 x 1 m or larger). Remote sensing (e.g., ground penetrating radar, magnetometers, soil resistivity) is mentioned in about half the reports. All but seven reports mention backhoe trenching as a deep testing strategy, but often only in passing, as mentioned above.

The standards and guidelines reviewed for this report, therefore, nearly always address subsurface testing, but most often mention deep testing only in passing, without elaborating on how and when it should be employed. These data suggest that, as in South Dakota, most states make decisions regarding deep testing on a case-by-case basis, with an awareness of, but no methodology for, the search for buried sites.

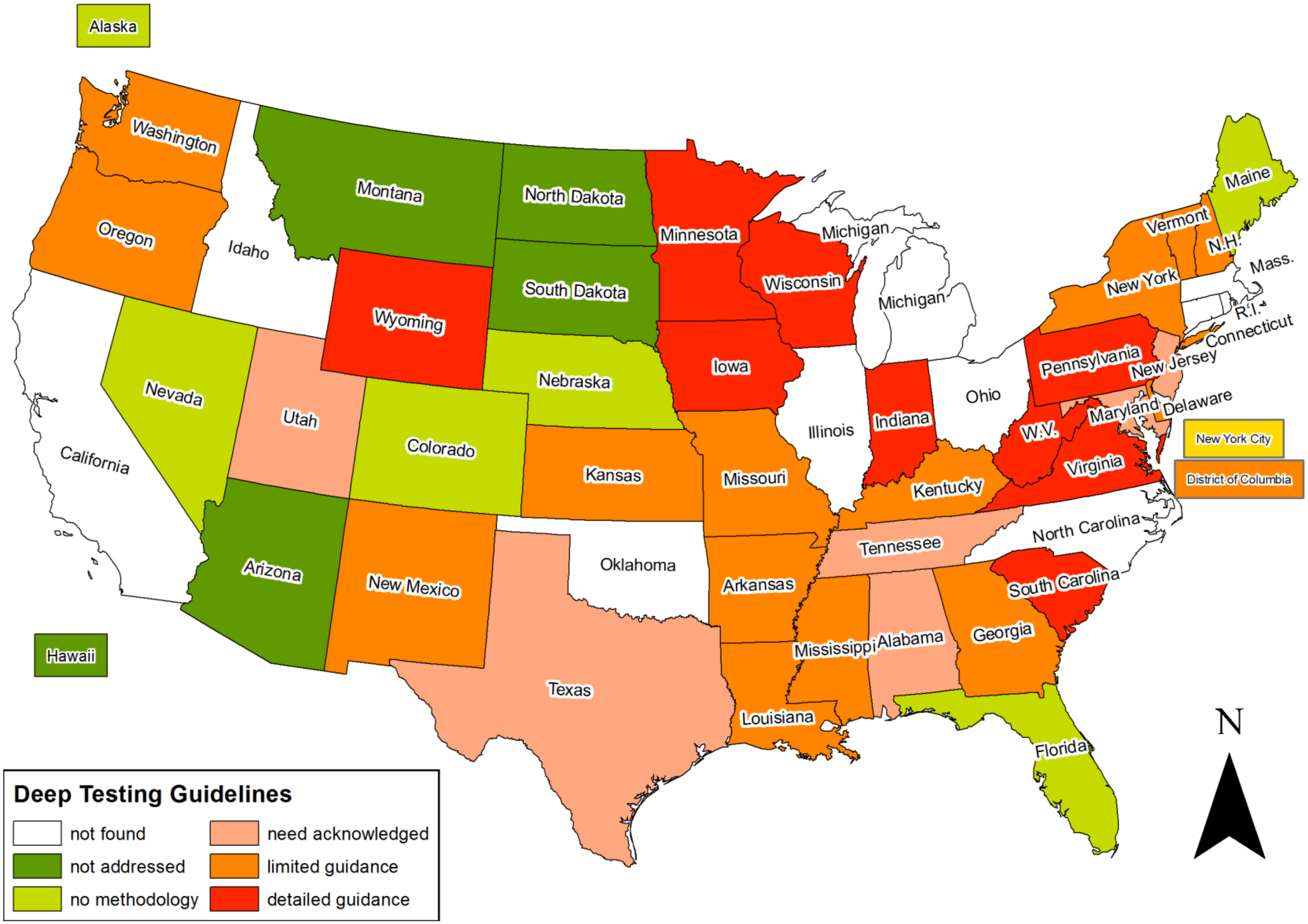


Figure 7. Map showing states for which archaeological survey guidelines were found, color coded to indicate how deep testing for buried sites is addressed.

Table 6. Summary of State Guidelines for Subsurface Testing.

			Methods Mentioned								
State	**Year**	**Deep Testing**	**Shovel Test**	**Auger Test**	**Test Pits**	**Back-hoe**	**Cores**	**Remote Sensing**	**Size, Depth, Intervals, Screening**	**Subsurface during Survey**	**Specialist Involve-ment**
Alaska	2003										
Colorado	2004										
Florida	n.d.										
Maine	1990										
Nebraska	2006										
Nevada	2010										
Alabama	2009	need acknowledged	X	X		x	x	X		X	
Arizona	n.d.		"hand excavation"	X		X					
Arkansas	2010	limited guidance	X	X	X	X	X		X	X	
Delaware	1993	limited guidance	X		X	X				X	
District of Columbia	1998	limited guidance	X		X	X	X			X	
Georgia	n.d.	limited guidance	X	X	X	X	X	X	X	X	X
Hawaii	2002		X		X						
Indiana	2007	detailed guidance	X	X	X	X	X	X	X	X	
Iowa	1993	detailed guidance	X	X	X	X	X	X		X	X
Kansas	2007	limited guidance	X	X		X			X	X	
Kentucky	2001	limited guidance	X	X		X	X		X	X	X
Louisiana	n.d.	limited guidance	X	X	X	X	X	X	X		
Maryland	1994	need acknowledged	X	X	X	X	X		X	X	
Minnesota, DOT	2005	detailed guidance		X		X	X		X	X	X
Minnesota, SHPO	2005	need acknowledged	X	X	X	X		X	X	X	

Table 6. Summary of State Guidelines for Subsurface Testing.

State	Year	Deep Testing	Methods Mentioned								
			Shovel Test	Auger Test	Test Pits	Back-hoe	Cores	Remote Sensing	Size, Depth, Intervals, Screening	Subsurface during Survey	Specialist Involve-ment
Mississippi	2001	limited guidance	X	X		X	X	X	X		X
Missouri	n.d.	limited guidance	X	X		X	X		X		
Montana	2003		X	X						X	
New Hampshire, DOT	2004	need acknowledged	X	X	X	X	X	X		X	X
New Hampshire, State Arch	2003	limited guidance	X		X	X					
New Jersey	2004?	need acknowledged	X	X		X	X		X	X	X
New Mexico	2006	limited guidance	X	X	X	X				X	
New York	1994	limited guidance	X		X	X	X	X	X	X	
New York City	2002	need acknowledged	X	X		X	X	X		X	
North Dakota	2006		X	X							
Oregon, fieldwork	2007	limited guidance	X	X	X	X	X	X		X	
Oregon, reporting	2009		X		X	X		X	X		
Pennsylvania	2008	detailed guidance	X		X	X	X	X		X	X
South Carolina, arch	2005	need acknowledged	X	X		X	X		X	X	
South Carolina, Geoarch	2005	detailed guidance	X			X	X			X	X
South Dakota	2005		X	X						X	
Tennessee	2009	need acknowledged	X	X	X	X				X	
Texas	n.a.	need acknowledged	X			X				X	

Table 6. Summary of State Guidelines for Subsurface Testing.

			Methods Mentioned								
State	**Year**	**Deep Testing**	**Shovel Test**	**Auger Test**	**Test Pits**	**Back-hoe**	**Cores**	**Remote Sensing**	**Size, Depth, Intervals, Screening**	**Subsurface during Survey**	**Specialist Involve-ment**
Utah, DOT	2010	need acknowledged	no specific methods given					X			
Vermont	2007	limited guidance	X		X	X	X	X	X	X	
Virginia	2009	detailed guidance	X		X	X	X	X		X	X
Washington	2010	limited guidance	X			X	X	X		X	
West Virginia	n.d.	detailed guidance	X	X	X	X	X	X	X	X	X
Wisconsin	1997	detailed guidance	X	X	X	X	X	X		X	X
Wyoming BLM	2003	detailed guidance	X	X	X	X	X				X
Total Count by Method			**38**	**27**	**24**	**35**	**26**	**19**	**17**	**31**	

Of the 43 documents that mention subsurface testing, a slight majority (25 of 43) do not provide specifications for the placement, size, depth, or screening of tests. Of the 18 that do offer such specifications, most refer only or primarily to shovel testing and other near surface methods. Even these 18 documents, however, leave the field archaeologists with much discretion in conducting subsurface testing.

Thirteen documents state that an earth science specialist may be brought into a project as part of deep testing efforts. Twelve of these 13 documents offer at least limited guidance in deep testing strategies.

A total of 30 documents consider deep testing as an activity that may be undertaken as part of the initial effort to discover previously unknown sites, prior to site testing and evaluation. Of these 30 documents, 24 documents are ones that provide guidance for deep testing.

The preceding discussion suggests that near-surface testing, primarily shovel testing, is a routine part of archaeological practice in the United States. The existence of contexts such as valley alluvium where sites may be deeply buried is also widely acknowledged, along with a need for specialist expertise. Specific guidance for searching for buried sites, however, is offered less often. Documents that offer specific guidance typically state that deep testing should be undertaken as part of the effort to find archaeological sites.

The ten documents that provide detailed guidance for deep testing at the equivalent of South Dakota's Level III survey are as follows:

- Indiana (Division of Historic Preservation: 2007);
- Iowa (Association of Iowa Archaeologists 1993);
- Minnesota State Historic Preservation Office (Anfinson 2005);
- Minnesota Department of Transportation (Monaghan et al. 2005);
- Pennsylvania (Bureau of Historic Preservation 2008);
- South Carolina (Schuldenrein 2005);
- Virginia (Virginia Department of Historic Resources 2009);
- West Virginia (Trader n.d.);
- Wisconsin (Kolb 1997);
- Wyoming (Bureau of Land Management 2003).

DETAILED STATE GUIDELINES

The purpose of the present project is to develop relatively detailed, deep testing guidelines for South Dakota. It is useful, therefore, to review examples of the general approaches and methods used in other states. The following sections summarize the guidelines developed for Indiana, Iowa, and Minnesota. These provide the most extensive guidance and cover virtually all the concepts, considerations, and methodologies laid out in the guidelines from other states cited above.

Indiana

In Indiana, Phase I is equivalent to South Dakota's Level III survey, and deep testing for buried sites is referred to as Phase Ic. Phase Ic guidelines (Division of Historic Preservation 2007) state,

> "Subsurface reconnaissance is required in areas where archaeological remains are likely to be buried in alluvial, colluvial, or aeolian landforms. This level of reconnaissance may require the use of small excavations, including trenches, to discover, define and assess the nature of buried deposits…. The subsurface reconnaissance attempts to find sites in both their vertical and horizontal exposures. Prior to the initiation of a subsurface reconnaissance, a plan must be submitted to the DHPA for approval…. Further, in extremely complex depositional situations, such as the large floodplains of the Ohio, Wabash or White Rivers, or alluvial/colluvial fans, the work must be supervised by a qualified professional with demonstrated ability in identifying and interpreting buried soil horizons and landforms. These

> individuals need to submit credentials and examples of their work to the DHPA for review. The need for this technical consultation will need to be addressed in the subsurface reconnaissance proposal."

The guidelines outline methods for controlled excavation, in levels, of backhoe trenches, and call for hand shovel skimming of trench floors. They call for deep testing on each type of landform (e.g., terrace, alluvial fan) in the APE, and state that, "An adequate, justified sample (rule of thumb, no less than 1% to 3%) of the land surfaces with the potential for buried archaeological deposits needs to be included in the subsurface reconnaissance." Testing intervals of 40-60 m are recommended for trenches, and 10 m for auger tests. The guidelines also set requirements for detailed soil description, trench profile mapping, back dirt monitoring, and feature and artifact collection and recording (Division of Historic Preservation 2007).

Iowa

Guidelines written by Iowa's Association of Iowa Archaeologist (1993) state that, "Some level of geomorphological assessment is essential for all phases [i.e., survey, testing, evaluation] of archaeological investigations." Deep testing as part of Level-III-equivalent surveys is required if the depth to deposits older than 12,000 years is >1 m, and the guidelines identify in some detail the landscape. Stream valleys receive particular attention. "Geomorphological evaluation of valleys must incorporate subsurface studies extending to depth where deposits that are not likely to contain primary archaeological deposits are encountered."

The guidelines include guidance for pre-field background research, field testing, and reporting of subsurface testing for buried sites. Sediment coring, manually or machines, is recommended for determining the potential for buried sites, but not for finding them, because of their small diameter (typically 2-7.6 cm). Test pits, backhoe trenches, posthole diggers, manual augers, and visual examination of natural and artificial cuts are identified as methods for discovering buried sites. Of these, auger testing is offered as the safest way to do testing because of limited depths of cutbanks and posthole diggers, and the danger of wall collapse for test pits and trenches. The guidelines specifically mention the Seymour auger, a T-handled posthole digger, named for a leading manufacturer of these tools. The tool is equipped with a 20-cm diameter bucket auger that, with extensions, can be advanced several meters into the ground, recovering samples in 10-20 cm intervals that can be described for stratigraphic information and screened for cultural material. Geophysical remote sensing is also mentioned as a subsurface prospection tool, with the caveat that ground truthing by the above methods is needed.

The guidelines require that Level-III-equivalent subsurface testing be conducted by a formally-trained and experience earth science professional, or by archaeologists who "have demonstrated professional expertise in field geomorphology through experience and publication" (Association of Iowa Archaeologists (1993).

Minnesota SHPO Guidelines

The Minnesota State Historic Preservation Office (SHPO) guidelines (Anfinson 2005) state,

> "Most soils in Minnesota that might contain archaeological materials date to the post-glacial or Holocene Period (last 10,000 years) and most soils that include archaeological materials are less than one meter deep. Sites in most of these situations can be discovered and evaluated through standard archaeological field practices [such as] shovel testing and standard hand-excavated test units. It is only when complex depositional settings are anticipated or encountered within the vertical and horizontal limits of a project that the SHPO deems it necessary for archaeologists to consult a professional geomorphologist. Such complex settings include areas of extensive alluvial, colluvial, or eolian deposition or areas where the natural soils have been subjected to complicated modern disturbances….
>
> The archaeological evaluation of river valleys, valley margins, and other settings where deeply buried deposits might occur must incorporate subsurface geomorphic studies extending to depths where

> deposits are not likely to contain primary archaeological materials or will not be impacted by a project. These studies should be aimed at determining the origin and approximate age of the deposits and strive to identify buried land surfaces. Sediments retrieved from buried soils should be screened through fine mesh (e.g., 25 mm) to recover microartifacts. This information will enable archaeologists to devise plans for subsurface testing" (Anfinson 2005).

Methods identified for testing to identify buried sites include manual or mechanical coring, augers, test excavation, backhoe trenches, examining existing exposures, and geophysical remote sensing. Use of trenching is discouraged "except to remove sterile or heavily disturbed overburden," because of potential destruction of archaeological deposits, wall collapse concerns, and landowner objections (Anfinson 2005).

The Minnesota Protocol

A second approach to deep testing is the so-called "Minnesota Protocol," developed by Monaghan et al. (2005) with funding from the Minnesota Department of Transportation as a process for buried site testing in Minnesota. Following the protocol is not required by SHPO (Anfinson, personal communication 2010), although the guidelines acknowledge that other agencies may require alternate methodologies than those advised by SHPO (Anfinson 2005).

The protocol is undertaken at the Level-III-equivalent Phase I of archaeological investigation (Monaghan et al. 2005). The decision to use the protocol is made on a case-by-case basis, and should be informed by landform mapping done as part of Mn/Model, a Minnesota-wide, archaeological predictive model (Hudak and Hajic 2001; Minnesota Department of Transportation 2005). The protocol was developed after an extensive study that evaluated and compared the cost-benefit and archaeological effectiveness of backhoe trenching, mechanical coring, mechanical augering, and remote sensing methods. That study concluded that backhoe trenching was the preferred method, supplemented by Giddings/Vibracore/Geoprobe coring. The purpose of coring is to trace the lateral extent of backhoe-exposed stratigraphy, to test deeper than backhoes can penetrate, or to test areas inaccessible to backhoes.

The objective of the protocol is to discover buried sites, although

> "the presence or absence of a site should be considered in terms of the observed stratigraphy and landform context as they relate to the Holocene developmental history of the area. This requires reconstruction of a three-dimensional model of the subsurface. When a buried archaeological site is not discovered, such a model can explain why and estimate the probability that undiscovered, buried sites are actually present but were not located during the deep testing. Consequently, more data than just presence or absence of archaeological materials should be collected during the trenching process (Monaghan et al. (2005).

Under the protocol, the first goal of subsurface testing is to determine the depth to basal deposits, defined as "Holocene alluvial deposits or depositional units that are unlikely to include archaeological deposits" (Monaghan et al. (2005). Trenching should follow OSHA safety guidelines, and include screening of samples from selected stratigraphic units for artifacts. A minimum trench length of 4 m is suggested, "the maximum length of the backhoe arm." The spacing interval between trenches is decided on a case-by-case basis.

> "In general, trenches should be placed initially to study the subsurface expression of specific surface depositional features that occur on the landform. Based on the results of these excavations, additional trenches may be placed to trace depositional features, soil horizons, or buried landform expressions in the subsurface.
>
> "….In developing a work plan and formulating a budget, the survey team should provide either a geomorphological and/or sedimentological map (based either on Mn/Model LfSAs or other criteria), and anticipate the number of trenches and trench placement strategy that will be required to test the landform

> components. The basic rational for trench numbers and placement should be outlined by the survey team as part of the work plan supplied to Mn/DOT" (Monaghan et al. (2005).

Excavation to as deep as the backhoe will reach, ca. 3-4 m, is recommended unless the water table or basal deposits are encountered. The protocol stipulates methods for profiling, flotation sampling, and radiocarbon dating.

Like trenching, coring or augering first establishes the depth to basal deposits.

> The principal goal of the coring process is to identify stratigraphic horizons that represent stable surfaces of an age compatible with human occupation. These are identified based on their stratigraphical, pedological, and sedimentological characteristics. The depths to the top and base of these horizons are defined based on the core data, and then these target horizons are sampled with augers for the buried archaeological materials.

To sample the "target horizons" using augers, the protocol pilot project used mechanically-drilled flight augers, 10-13 cm in diameter and (typically) 1.2-1.8 m long. An example of a flight auger is the screw-type drill attached to the power augers commonly used for subsurface testing in the Dakotas. Those used on core and drill rigs are designed to connect together into long, continuous strings, called "flights." The pilot study did augering on 20 m grids. At each point on the grid, multiple auger holes were drilled, enough to test a sampling volume equivalent to that of a 25 cm diameter shovel test. This required 4-6 individual holes, depending on auger diameter.

Discussion

The guidelines presented above view deep testing as part of Level-III-equivalent intensive survey. A difference between them is that Iowa's recommends that geomorphological study be conducted in advance of the archaeological survey (Association of Iowa Archaeologists 1993). The rationale is that archaeological survey of alluvial, colluvial, and eolian landscapes should not begin until the archaeologists know about subsurface conditions. For example, pedestrian surface survey need not be undertaken in areas covered or entirely underlain by historic-period alluvium, where surface prehistoric sites will not exist. Further, the premise is that, prior to starting subsurface testing, archaeologists should know where and how deep testing should extend.

In practice, in Iowa, the additional time and cost of "doing the geomorphology first" has proven to be impractical except for relatively large projects where complex depositional sequences make an initial geomorphological investigation essential. For small and quite a few large projects, archaeologists working in Iowa generally do the geomorphology "as they go."

The Minnesota protocol summarizes the relationship between geomorphological and archaeological investigations as follows,

> "The discovery and evaluation of buried archaeological sites is a multidisciplinary task that focuses on two different aspects of geoarchaeology. The first, discovery, emphasizes the "geology" of geoarchaeology while the second, evaluation, focuses on the "archaeology" of the discipline."

To that extent, the Indiana guidelines and Minnesota protocol, as well as other states, establish a methodological approach that accomplishes both the geology and the archaeology at the same time. For example, both documents recommend that trenching proceed in systematic intervals, carefully peeled back with a smooth-bladed bucket to find artifacts as well as expose stratigraphy. Flight-augering in the Minnesota protocol is designed to sample volumes equivalent to a standard shovel test.

Not surprisingly, in the field, the Iowa "do it first" and Minnesota/Indiana "do it together" approaches are rarely mutually exclusive. The Minnesota protocol requires that subsurface testing begin with a geologically oriented effort to find the depth to basal deposits, followed by closer interval trenching or augering to search for sites. In Iowa, archaeologists will frequently skip over, or widen sampling intervals, in landform contexts where professional judgment indicates archaeological deposits are unlikely.

The purpose of the "geo" part of geoarchaeology is to identify where, and at what depths, buried sites are likely to occur. The "archaeological" part is to actually find the sites. An important point is that a geological investigation that focuses only on the geology does little to contribute to the project's ultimate, if not only goal, which is to find and evaluate sites (Anfinson 2005). That is the only way in which the application of earth science methods and techniques can be cost-effective and valid from an archaeological – or more precisely, geoarchaeological – perspective.

Concepts and Considerations

This section identifies several topics that were considered in developing buried site guidelines for South Dakota. The effectiveness of the guidelines is partially dependent on how the concepts and considerations presented below are put into practice in implementing the guidelines.

BURIED SITE POTENTIAL

Table 7 expands on Eigenberger et al.'s (2009) categories of buried site potential, previously quoted. Each category is defined in terms of geological indicators and their archaeological implications. The geologic indicators are lithologic and stratigraphic properties that are observable in the geologic record and can be used to evaluate if the sediments were laid down in an environment conducive to the burial and subsequent preservation of archaeological deposits. The archaeological implications involve field methods that are necessary to do the evaluation, and to determine the appropriate depth of subsurface testing.

SUBSURFACE TESTING METHODS

Subsurface testing methods vary in the depth to which they penetrate, the volume of soil they can extract, their usefulness for exposing stratigraphy, the level of effort and cost of using them, and other factors (Stein 1986; Kolb 1997). The first method discussed, monitoring, is the method perhaps most often employed in South Dakota. It is undertaken during or slightly in advance of, construction, and with few exceptions, involves machine-excavation. (Buechler 1983; Buhta 2009; Pysarsky 2002)

Other methods are discussed below in approximately increasing order of the size and volume of sediment they recover. They are also in approximate order of the depth to which they can penetrate, and in their reliance on machinery.

Monitoring

As stated above, monitoring occurs during or just prior to construction. The specific method is usually that used in construction itself, for example, backhoe trenching for a pipeline, belly-scrapers for a borrow pit. In South Dakota, it is often recommended by consulting archaeologist and agencies alike, and is preferred by most, if not many, tribal governments (Paige Olson, personal communication 2011). Monitoring is usually undertaken in situations where a Level III survey, finds no significant sites at or near the surface, but where the geological context is judged to hold potential for buried archaeological deposits. If undertaken in advance of actual construction, monitoring can result in intensive, systematic testing. For example, advance monitoring using a backhoe can be undertaken with smooth bladed buckets in 5-10 cm intervals, as described above, preferably far enough in advance to allow timing for examination of soil profiles and discovery/recovery of archaeological materials. Advance monitoring requires close scheduling with the construction contractor to avoid delays.

Table 7. Criteria for Evaluating Buried Site Potential in South Dakota.

Category	Description

High	**Geological Indicators:**
	• Low-energy depositional processes are dominant, yielding strata that are:
	  o conducive to preserving buried archaeological deposits in primary context, with stratigraphic integrity, and
	  o thick enough to have the potential for stratigraphic separation of archaeological components, either in vertically-stacked buried soils, or in environments with high sedimentation rates.
	• Buried soils are diagnostic, but do not need to be present for buried sites to occur. If present, buried soils provide stratigraphic markers for tracing occupation surfaces laterally, and are good indicators of episodic deposition, stable surfaces, and potential for stratigraphic separation of components, all of which can contribute to the National Register eligibility of a buried site.
	Archaeological Implications:
	• If buried deeper than 50-100 cm, subsurface testing is necessary to detect and determine the boundaries of archaeological deposits
	• Archaeological deposits within 50-100 cm of the surface can be discovered by near-surface methods like shovel and auger testing. They may also be exposed at the surface by rodent burrowing, erosion rills/gullies, tree throw, frost heaving, and similar processes.
	• For cultural deposits discovered in cutbanks or other sediment exposures, subsurface testing may still be necessary to determine their lateral extent.

Moderate	**Geological Indicators:**
	• Depositional processes yield stratigraphic sequences that are
	  o conducive to preserving buried sites, but
	  o have been modified by high energy or erosional processes such as deflation, channel cut-and-fill, or mass-wasting that have reduced the possibility that intact archaeological deposits are preserved.
	• Buried soils, if present, will be weakly developed and thin.
	• Sedimentary deposits with moderate potential will exhibit both lateral and vertical variability in stratification, indicative of fluctuations between high and low energy deposition, and/or deposition and erosion.
	Archaeological Implications:
	• Cutbank exposures or aerial imagery interpretation may sometimes be sufficient to determine that the APE has been subject to fluctuating energy regimes. In other cases, such evidence is only present in the subsurface and can be detected by surface testing.
	• In moderate potential sedimentary deposits, subsurface investigation might focus on detecting “pockets” of low energy sediments and, if found, testing them for the presence of archaeological deposits.
	• In some cases, high potential deposits may overlie or underlie moderate potential ones, or transition laterally from one to the other.

Low	**Geological Indicators:**
	• Sediments are either:
	  o too old or too thin to contain buried archaeological deposits in primary context with stratigraphic integrity, or
	  o accumulated in high-energy depositional environments such as stream beds or debris flows where both habitability and preservation would be unlikely.
	• Low potential is inherent in erosional landscapes characterized by steep slopes, erodible parent materials, and thin mantles of sediment over bedrock, till, or outwash.
	• Soil development will be very weak or absent due the lack of land surface stability.
	• High energy transport environments are characterized by sandy and gravelly textures, or interbedded gravels, sands, silts, and clays that were deposited within stream channel, in sand or gravel bars within the active channel belt, or debris flows.

Table 7. Criteria for Evaluating Buried Site Potential in South Dakota.

Category	Description
Low	**Archaeological Implications:** • No subsurface testing is needed in low potential environments. • Cutbank exposures, aerial imagery, surface evidence of severe erosion may be sufficient to determine the age, thickness, and energy regime of the APE. • In other cases, such evidence is not detectable at the surface but can be identified by subsurface testing. • Particularly in alluvial environments, low potential, high-energy channel deposits will often underlie a low-energy, high potential environment. In rockshelters, roof fall (high energy) may cover lower-energy deposits containing archaeological deposits.

If conducted during construction, the monitoring archaeologist is constrained by construction methods in the kinds of exposures available for observation. In a trenching situation, for example, trenches may be sloped back at an angle that does not provide clean profiles. Construction-related excavation may also occur at a pace, and over an area, that precludes the monitors from being able to effectively or safely view sediment as it is removed.

The risk of monitoring, especially if concurrent with construction, is that a National Register eligible site will be encountered, and construction is delayed or halted. The author has seen such contingencies handled in two ways. In one example (Artz et al. 2003), a sewer project involving an impact area 30 m wide and 10 m deep, the contingency of discovery was written into the construction contracts, requiring the contractor to plan in advance for possible delays. This provision was part of the memorandum of agreement (MOA) among the SHPO, the lead agency, and other interested parties, executed in the planning stages of the undertaking as part of the Section 106 review and compliance process. A second example involved the construction of a septic system in the Knife River Flint primary source area of North Dakota. Construction-concurrent monitoring was undertaken with the understanding between SHPO and the federal agency that if archaeological deposits were encountered during monitoring, areas adjacent to the site would be excavated to accomplish National Register evaluation (Artz 2010).

Both are examples in which the specific location of the undertaking was such that significant, subsurface, archaeological deposits were reasonably anticipated, and in fact, were discovered. In many, if not most cases, an implicit assumption of monitoring is that the chance of encountering such deposits is low, and therefore the risk of delay is very low.

Pedestrian Survey

Pedestrian methods allow the inspection of cutbanks, construction excavations, animal burrows, erosional cuts, and other sediment exposures for buried sites. This method is commonplace in Level III survey, and results in the discovery of many buried sites. It is limited by the availability of exposures, and their depth. Bank exposures are most numerous and deepest along the eroded lake shores of the Missouri Trench.

Shovel Tests

Shovel testing is a standard archaeological method, used nationwide, as previously discussed (Table 6). The technique exposes a soil profile that can be described in detail. Shovel testing becomes increasing difficult below depths of 50 cm, and can only detect near surface archaeological deposits.

Soil Probes

Soil probes, like those manufactured by Oakfield (http://www.soilsamplers.com/; http://www.jmcsoil.com/), range in diameter from .75-1 inch. Pushed or driven into the soil, they bring up a solid core of sediment that is sufficient to identify lithologic and soil properties and stratigraphic boundaries. They are too small for artifact sampling, and therefore should be considered a stratigraphic, not site identification tool. With extensions and a rubber mallet to drive the core into the ground, the author has sampled to depths of 3 m with these tools. Sliding hammers and power-hammers make deep sampling easier.

Bucket Augers

Bucket augers, like those manufactured by AMS (http://www.ams-samplers.com/) are a standard tool for soil scientists. They range in diameter from 2¼-3 in, and with extensions can be advanced to depths of 3-4 m. The auger bit allows soil to enter the bucket relatively undisturbed, although some twisting and distortion of the sample occurs, due to friction with the side of the bucket. They are adequate for describing soil and sedimentary properties and detecting stratigraphic boundaries. Small-scale features such as very thin beds (laminations) of sand and silt are often difficult to discern because they get mixed together with the surrounding matrix. The small diameter reduces their usefulness for artifact sampling.

Posthole Diggers

Posthole diggers of the two-handled, “clam shell” type penetrate to depths of 1-1.2 m, and can dig a hole the same diameter as a circular shovel test. The holes can be excavated in levels for stratigraphic control of artifact recovery. At depth, profiles cannot be observed, but if the extracted soil often comes up in intact chunks large enough for description purposes. To be used effectively, the sharp blades have to strike and penetrate into the bottom of the hole with considerable force, risking damage to artifacts, if present. They are best not used on sites with high artifact density or fragile materials like bone or ceramics.

Power Augers

Power augers are used fairly commonly for site prospection in the Dakotas. Those in common use excavate a 20-25 cm hole to depths of 1-1.2 m. Donohue and Davis (2003) report the use of a tractor mounted, 50-cm diameter auger. These devices churn the soil, and are too small in diameter to accurately observe stratigraphic boundaries. They are therefore not amenable to soil description, and there is no depth control on recovered artifacts.

Test Units

Test units, 1 x 1 m or larger, are used for subsurface testing and provide excellent stratigraphic control and profiles. They have been excavated to depths of up to 3 m, and perhaps more, but if excavated deeper than 1.5 m, need to be stepped back or shored for worker safety and OSHA compliance.

Posthole Augers (Manual)

Bucket-auger-style posthole diggers. These manual, T-handled posthole diggers are the standard tool for subsurface testing in Iowa. They consist of an open-sided bucket auger, 20 cm in diameter. As purchased at a hardware store, they reach a depth of 1.2 m, but with the addition of ¾” steel pipe extensions, can be carried to greater depths. In Iowa and other Midwestern states (Abbott and Neidig 1993; Artz et al. 1995; Artz and Bettis 1993; Stafford 1995), they are routinely used to reach depths of 2-3 m. The author has excavated with them to depths of up to 6 m in alluvial fan deposits. In loam, silt loam, and silty clay loam soils, a bucketful of soil is recovered every 10 cm of depth, and thus stratigraphic control can be maintained in a standard depth interval. A disadvantage is that the auger blades are close-set, and the excavated soil is extensively churned. This disrupts soil structure and fine sedimentary layers, but soil color, texture, mottles, and carbonate/iron/manganese concretions can be recorded. These properties are more than sufficient to identify the depositional environment to a degree sufficient to determine buried site potential. Notes on stratigraphy can be made as the hole is dug. A better method is to take lay out samples of soil from each level in a row on the ground, and then record them at once as a continuous profile.

Drill Rigs

Drill rigs extract solid, continuous cores to depths of >4 m. Giddings rigs push sampling tubes into the soil using a hydraulic piston, and can also rotate a flight auger into the soil. The most commonly used tubes are 5-7.5 cm in diameter, although tubes up to 20 cm in diameter are available. Rigs can be mounted on trailers, truck beds, tractors, and six wheel all-terrain vehicles.

Other core rigs in common use are the Vibracore and Geoprobe. The Vibracore minutely shakes the sampling tube at 3,000-11,000 vibrations, loosening a thin layer of soil around the tube, allowing it to penetrate the ground. A Geoprobe uses rapid, percussive force from a hydraulically powered hammer to drive the sampling tube.

The advantage of drill rigs is the extraction of a solid core that is large enough in diameter for a relatively detailed description of the sediments. The core tubes are open at the bottom, so there is minimal twisting or churning of the sample, although compaction of cohesive sediments can be a problem, especially with the Giddings. The disadvantage for archaeological purposes is that the small diameter decreases the probability of finding cultural material. Therefore, drill rigs are usually used to work out stratigraphy rather than find sites.

Flight Augers

Flight augers are drilled into the ground like a screw, using spiral augers, connected to together to form a continuous string of auger sections, called flights. Flight augering can be done with the kinds of drill rigs mentioned above. The method was proposed and tested by Monaghan et al. (2005). For a discussion of this method see the preceding section “Minnesota Protocol.”

Backhoe Trenches

Backhoe trenches provide excellent profiles. Especially when equipped with a smooth-bladed, rather than toothed, bucket, backhoes can skim soil in horizontal slices, 5-10 cm thick, sufficient for detecting artifacts and features in situ. Depending on the size of the machine, trenches can be excavated from the ground surface to depths of 6 m. For safety and OSHA compliance, excavations deeper than 1.5 m should be shored or stepped back before personnel enter. In practice, this often means that a trench is first dug to 1.5 m, entered and described, and then carried to depth. This limits the ability to see and recover artifacts, and sediment descriptions must be made from chunks brought to the surface by the machine.

Ditch Witch Trenches

Ditch Witch trenchers are designed for excavating trenches for small diameter utility lines. They use a continuous chain, mounted with small, backhoe-like scoops to dig a narrow trench, 20-30 cm wide by 2-2.5 m deep. Back dirt is laid alongside the trench. Odell (1992) found the machines useful for minimally invasive testing of an archaeological site. He systematically sampled for artifacts by ¼-in-dry-screening “a linear meter” of back dirt every 10 m. Pysarski (2002) used a Ditch Witch in construction monitoring for a project on the Cheyenne River Reservation, South Dakota.

Remote Sensing

Geophysical remote sensing, in the Dakotas, has been employed primarily to discover and map subsurface archaeological features and artifacts on known sites. Examples include investigations at Fort

Pierre-Choteau (Kvamme 2007), Whistling Elk (Kvamme 2001; Toom and Kvamme 2002), and the steamboat *North Alabama* (Devore 1998) to seek and map subsurface archaeological features.

The same geophysical techniques employed by archaeologists (Kvamme 2001) are also used in the earth sciences to map stratigraphic contacts. Ground penetrating radar can detect abrupt stratigraphic boundaries (Kvamme 2001) and thin bedding structures in sand dunes (Baker and Lol 2997). Electromagnetic induction is sensitive to the characteristics of different kinds of sediment and is used to detect the contact between fine-grained sediments (alluvium, loess) and bedrock (Davis 2011). Resistivity is used to trace subsurface stratigraphic contacts in alluvial sediments (Zanetske et al. 2006).

Discussion

Each of the above techniques has advantages and disadvantages. Shovel tests, excavation units, posthole diggers, and power auger tests, are most often used by archaeologists, but are limited to the depth they can penetrate, and are therefore not useful for deep site testing. Although 1 x 1 to 2 x 2 test units have been carried to depths of several meters in South Dakota and elsewhere, such units should not be carried below 1.5 m unless shored, both for safety and OSHA compliance.

Coring rigs, soil probes, and small-diameter, "soil-science" bucket augers can be extended to depths of several meters, and can recover samples from below the water table, but are small diameter which seriously reduces their effectiveness at finding archaeological sites.

Where high to moderate potential sediments exceed 1 m in thickness, the author recommends backhoe trenching, posthole-type bucket augering, or flight-augering for deeply buried site detection. Backhoe trenches can reach to depths of 3 m or more, and expose long continuous profiles capable of detecting features and artifact layers. If deeper than 1.5 m, however, shoring or stepping is required, and trenching is not effective at depths below the water table. Hand-augering and flight-augering offer advantages over trenches by penetrating deeper, allowing systematic screening for artifacts, and eliminating dangers of wall collapse, but are more labor-intensive. They are limited, however by their small diameter (commonly no larger than 20-30 cm).

Although some advocate one method over others (e.g., Monaghan et al. 2005), in practice, some tools are more practical than others in given situations. Oahe Formation loess and sand sheets, for example, if less than ca. 1-1.5 m thick, can adequately be tested with shovel, auger, or posthole tests. Thicker alluvial deposits, however, require tools capable of reaching greater depths. Another factor is the level of archaeological investigation being undertaken. Coring with drill rigs can rapidly determine the general stratigraphy of a project area, providing information for defining the vertical APE and developing a strategy to seek sites. However, if continuous exposures are needed (for example, to expose the cross section of a dune or terrace contact), a backhoe trench is more suitable.

Another significant factor in a cultural resource management context is the risk of construction delays. Generally speaking, completing subsurface testing during Level III surveys, conducted well in advance of construction, significantly lessens this risk. The longer subsurface testing is delayed, the greater risk that deeply buried archaeological deposits will interfere with construction schedules. The risk is greatest for monitoring. The need for, depth, and timing of subsurface testing to discover archaeological sites always involves a trade-off between the risk to the nonrenewable archaeological record of adverse impacts to a significant site, and the risk that a specific undertaking will encounter and adversely impact a site.

OTHER SUBSURFACE DATA SOURCES

Geotechnical Borings

An important part of the design process for many construction projects is doing subsurface borings to determine the engineering properties of the soils. In addition to obtaining samples for laboratory testing, the stratigraphy encountered in drilling the bore holes is described and reported in the form of a stratigraphic log. The logs are presented as part of a geotechnical report, along with maps showing their location within the construction site. Geotechnical logs are not as detailed as geoarchaeological descriptions, which typically employ NRCS terminology (Schoenenberger et al. 2003). Detailed descriptions are not necessary, however, for a preliminary assessment of buried site potential. Artz (2006) demonstrated the feasibility of using geotechnical logs to differentiate high potential, low-energy overbank sediments from high-energy, low potential channel sediments. He used the thickness of the overbank deposits to estimate the potential depth to which buried sites might occur.

To test the applicability of this approach to South Dakota, bore logs for a sample of bridge replacement projects were obtained from the South Dakota Department of Transportation. In South Dakota, geotechnical borings are used to assess the engineering qualities of the soil into which bridge pilings or piers will be set (John Weeldrier, DOT, personal communication 2011). The stratigraphy encountered in each boring is shown on the design plans as columns, divided into strata differentiated on the basis of properties such as color, texture, and consistence. The strata are connected to create a stratigraphic cross section.

For this analysis, bore log data were sought for bridges spanning the Grand, Moreau, Cheyenne, Belle Fourche, Bad, James, and Big Sioux Rivers (Figure 8). The Missouri River was not considered since its Holocene geomorphology and buried site potential are relatively well known. Crossings were selected from the upper, middle, and lower thirds of each river's length in South Dakota. Candidate bridges were examined in GIS on a base layer of true color aerial imagery. To be selected, the valley had to intersect more than one mappable landform unit, and preferably cross the valley orthogonal to its downstream axis, to provide a more readily interpretable cross section. Crossings were not selected from the South Fork Cheyenne River, because the extensive drilling done in this valley by Hajic (2008) provided subsurface coring data.

A list of 19 bridges was sent to Terry Erickson, GIS Program Specialist, and John Weeldrier, Assistant Foundation Engineer, at the SDDOT. Weeldrier pulled files for 17 bridges for which data could be located. He digitally scanned the documents and provided them to OSA as PDF files.

In representative stratigraphic cross sections (Figures 9-11), elevations in ft are shown for a vertical scale. The horizontal scale is indicated by station numbers across the top. Disregarding the "+" sign, these are read as feet from an origin point. For example, station numbers of 21+00 and 22+00 are located 2100 and 2200 ft from the 0+00 station, and are 100 ft apart.

Figures 9-10 show stratigraphic cross sections at bridges on the Belle Fourche, Moreau, Big Sioux, and James Rivers. The borings are taken to or into bedrock or glacial till, and therefore the whole thickness of alluvium is penetrated. Alluvium thickness ranges from 2-70 ft (0.6-21 m). Stratigraphic layers are interpolated between cores. In most bore holes, the sediment layers fine upward, as expected of alluvium. Buried site potential would be highest in the low-energy silt and clay strata, and lowest in sandy and gravelly strata.

The utility of these cross sections for geoarchaeological purposes, though, is lessened because they traverse only a tiny portion of the valley floor. The South Dakota DOT rarely takes borings beyond the actual length of the bridge (John Weeldrier, personal communication 2011). The width of the cross sections in Figures 9-10 varies from 160-500 ft (49-152 m), whereas total valley width at the bridge locations is a kilometer of more. Thus, only sediments immediately adjacent to the channel are tested, and these are usually historic-period floodplain surfaces.

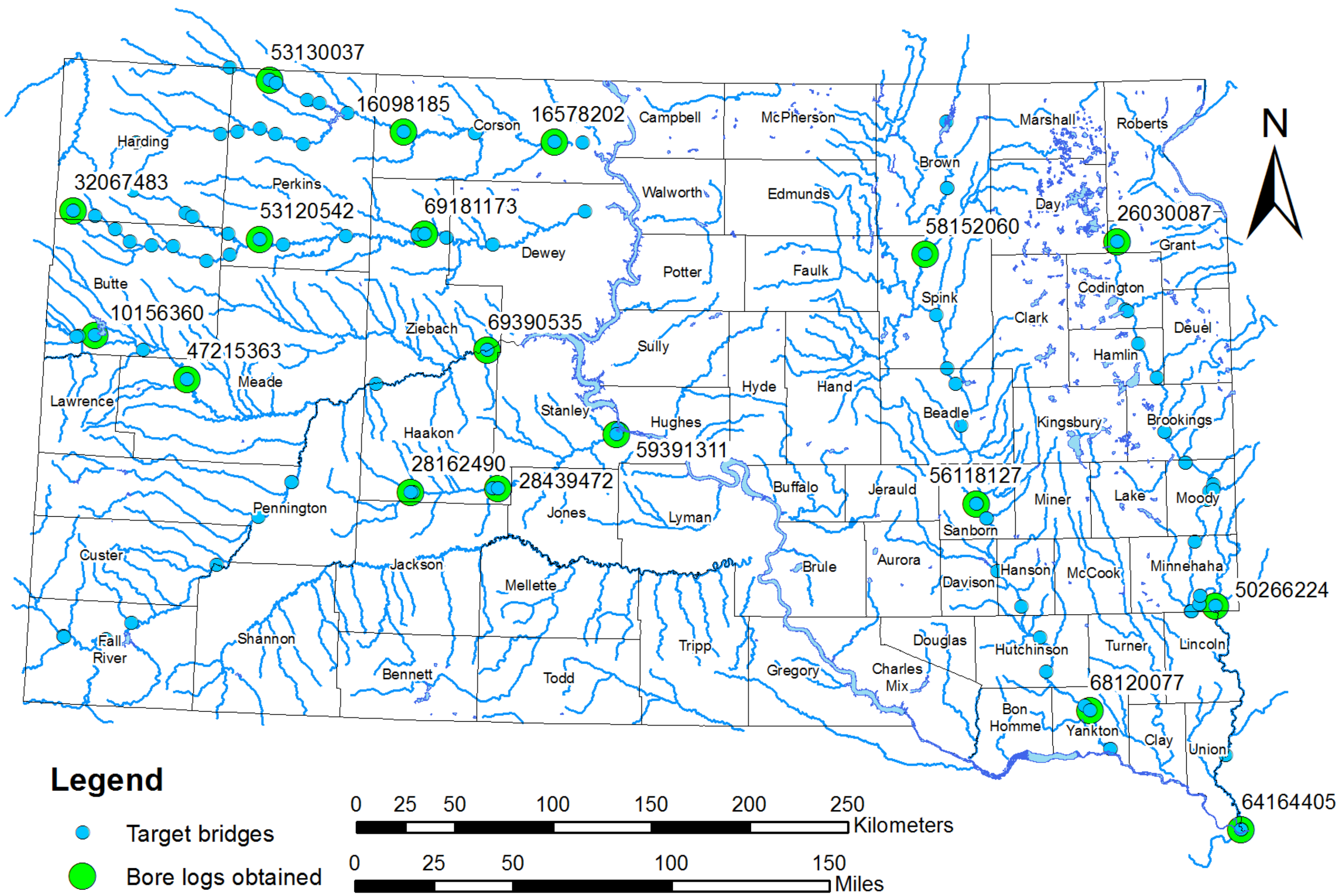
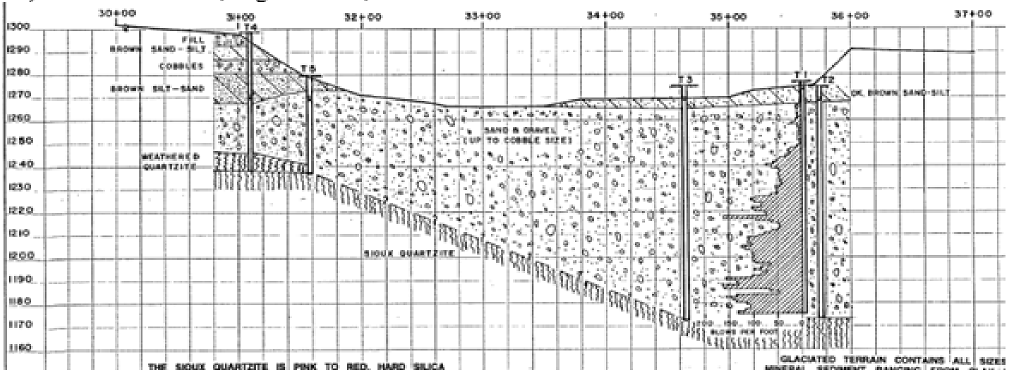
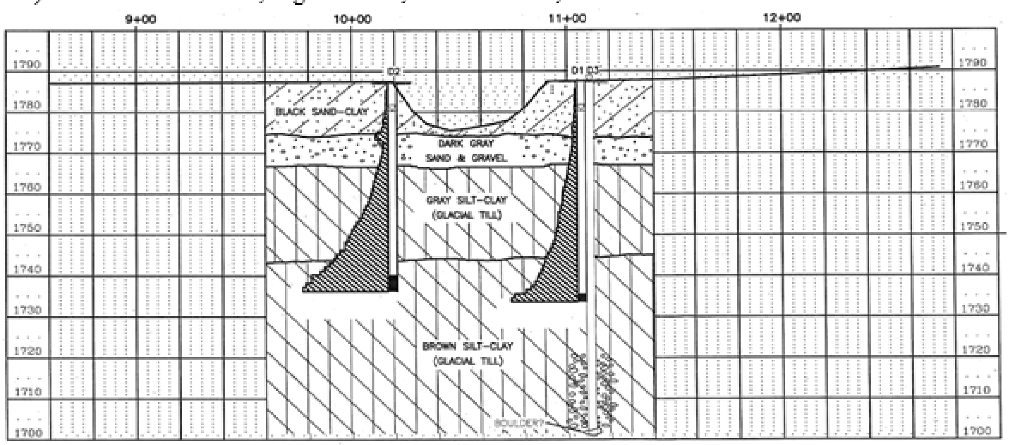


Figure 8. Location of selected bridges on major rivers in South Dakota, showing the SD DOT bridge ID numbers of those for which geotechnical logs were examined.

a) 50266224: SD 42, Big Sioux R., 5-50 ft to bedrock



a) 26030087: 452 AVE, Big Sioux R., ca. 20 ft to till,



b) 58520610: SD 20, James R.: ca. 70 ft to glacial till

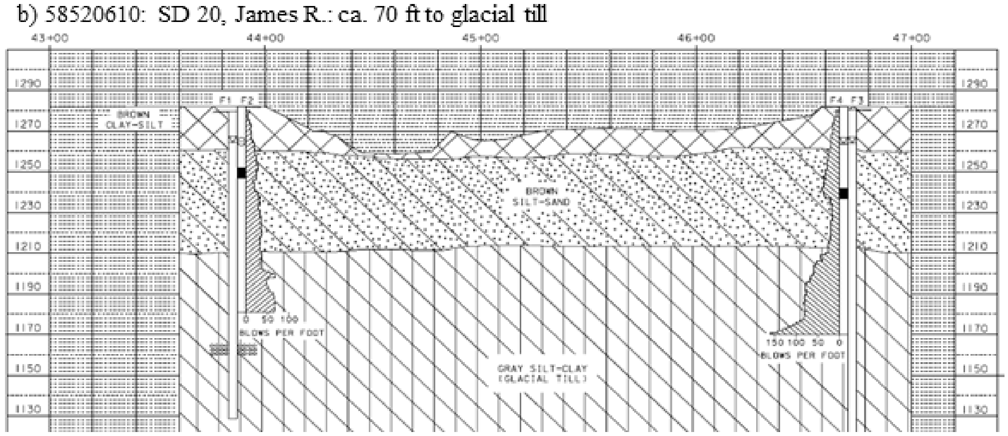
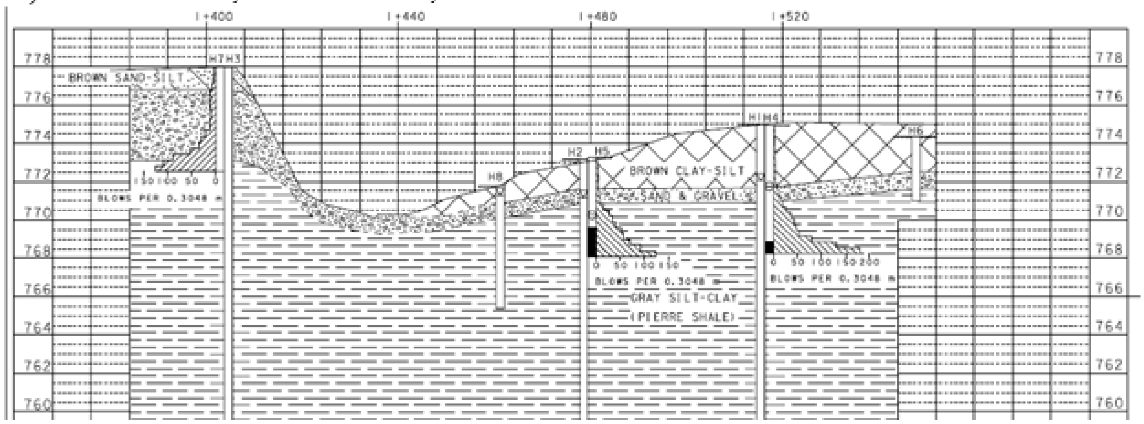
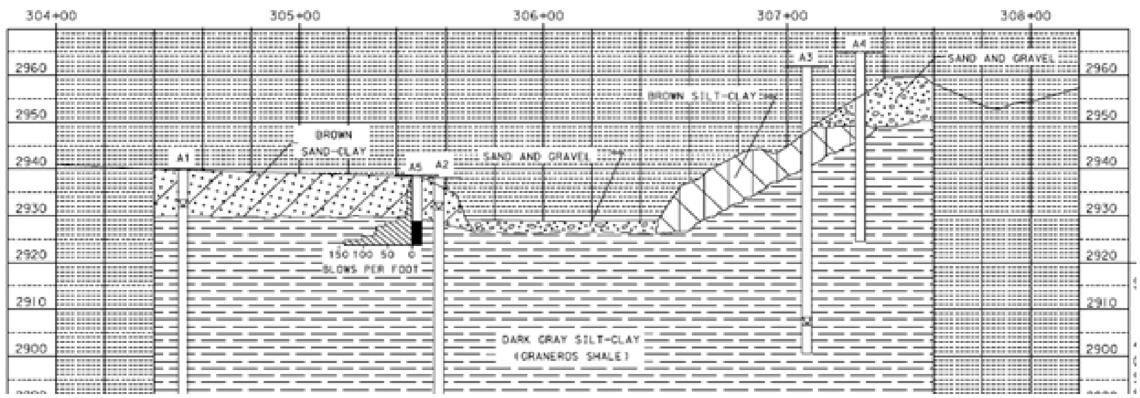


Figure 9. Representative stratigraphic cross sections of alluvium at three East River bridges (source SD DOT design plans.

a) 47215363: SD 34, Belle Fourche R., 2-5 ft to bedrock



b) 10156360: US 212, Belle Fourche R., 10 ft to bedrock



c) 53120542: Cedar Canyon Road, Moreau R., 25-30 ft to bedrock

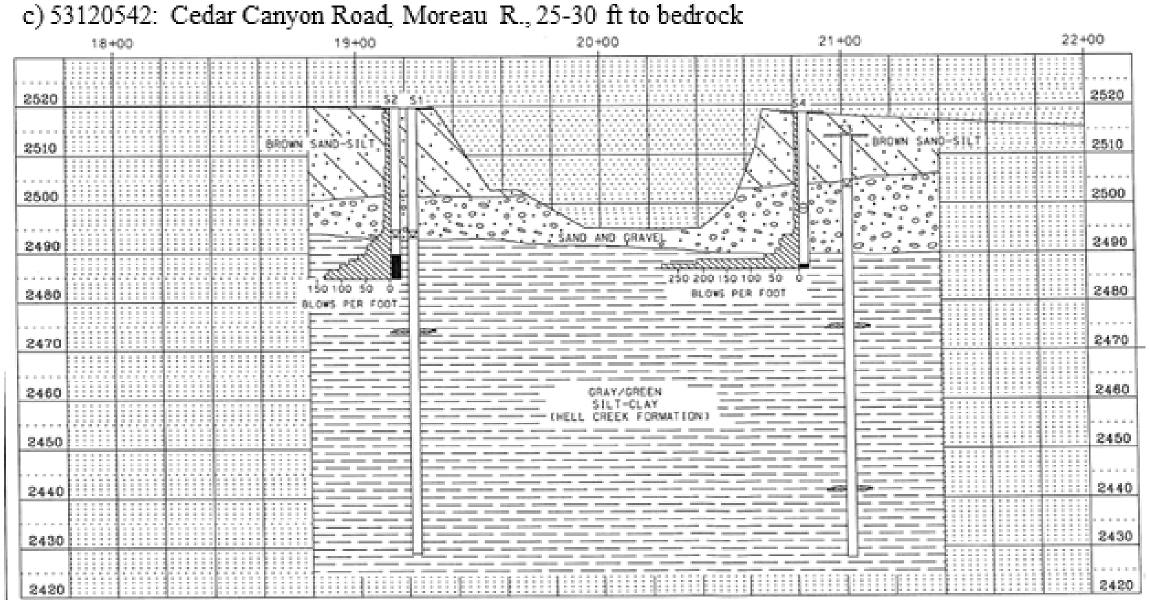


Figure 10. Stratigraphic cross sections of valley alluvium from three West River bridges. Source: SD DOT design plans.

Figure 11 is a stratigraphic cross section of a 2400-ft-long (740 m) stretch of the Lower Cheyenne River in Ziebach and Haakon counties. The present channel is shallowly incised into a fine-grained clayey silt and fine silty sand, 10-20 ft thick. This is underlain by channel gravels that form an undulating paleotopography of gravel bars and troughs. At the northwest end of the transect, the bore logs are interpreted to represent an interfingering of gravel and silts. The alluvium is underlain by Pierre Shale. A trough northwest of the present channel in the bedrock surface indicates that at one time the channel was incised ca. 6 m into bedrock.

Although much wider than the sections shown in Figures 9-10, the cross section in Figure 11 underlies a low-lying, periodically inundated surface at the west end of an arm of Lake Oahe (Figure 12a). The USGS quadrangle and aerial photograph (Figure 12b) indicate that a higher terrace surface is located to the northwest of the end of the bore hole transect.

Because of their narrow extent, the South Dakota DOT geotechnical borings may not be of much assistance in assessing buried site potential. More useful would be cross sections that intersect multiple surfaces, including higher terraces, alluvial fans, and colluvial slopes. Other kinds of large engineering projects require geotechnical studies, sometimes distributed over large areas. The examples shown here indicate that geotechnical borings can provide certain baseline information about a survey area, most importantly, the thickness of fine-grained overbank alluvium that has the greatest buried site potential. Although no substitute for field investigation, geotechnical logs could assist in planning fieldwork. For example, knowing the potential thickness of high potential alluvium could be used to anticipate the amount of time needed to drill or trench to the base of the high potential sediments. Simply stated, time and cost increase with the thickness of the Holocene, and any advance knowledge of that parameter will be useful in developing research designs for subsurface testing.

Geological Maps

Sources in addition to the 1:500,000 state geological map (Martin et al. 2004) are available for estimating the distribution of buried site potential, and are probably preferable because they are prepared at lower scales. County geological maps published by the South Dakota Geological Survey are available as pdfs for most counties at 1:62,500 scale. More recent ones (e.g., McCormick and Hammond 2004) are available in GIS format. Even greater detail is offered by an in-progress series of Black Hills geological maps at 1:24,000 (e.g., Redden et al. 2010). The modern maps digitize valley alluvium and eolian sediments in considerable detail and would provide better estimates of the aerial extent of landscapes and landforms with high archaeological potential.

Aerial Photographs and USGS Quads

USGS topographic maps at 1:24,000 scale and National Aerial Imagery Program (NAIP) aerial photography are useful for identifying landforms with buried site potential. Topographic features with more than 3 m (10 ft) of relief are discernable on the USGS quadrangles, including terrace scarps, dunes, playas, colluvial fans, and colluvial slopes. These features are also identifiable in tonal patterns discernible on NAIP and other aerial photogrammetry series. This is particularly the case in western South Dakota, where the dry climate and sparse vegetation can make very low relief geomorphological features stand out, usually because of contrast between moist and dry soils, between bare and vegetated earth, or between different soil types, slopes, or similar factors that influence plant types and ground cover. In alluvial valleys, former channels and meander belts stand out because they are lower lying (therefore moister) and clayier in soil texture, both of which result in darker tones on photographs. Fans are often clearly delimited by individual splay-like lobes spreading from the mouth of their feeder valleys, or by subtle, radiating channel patterns that distribute sediment across the fan.

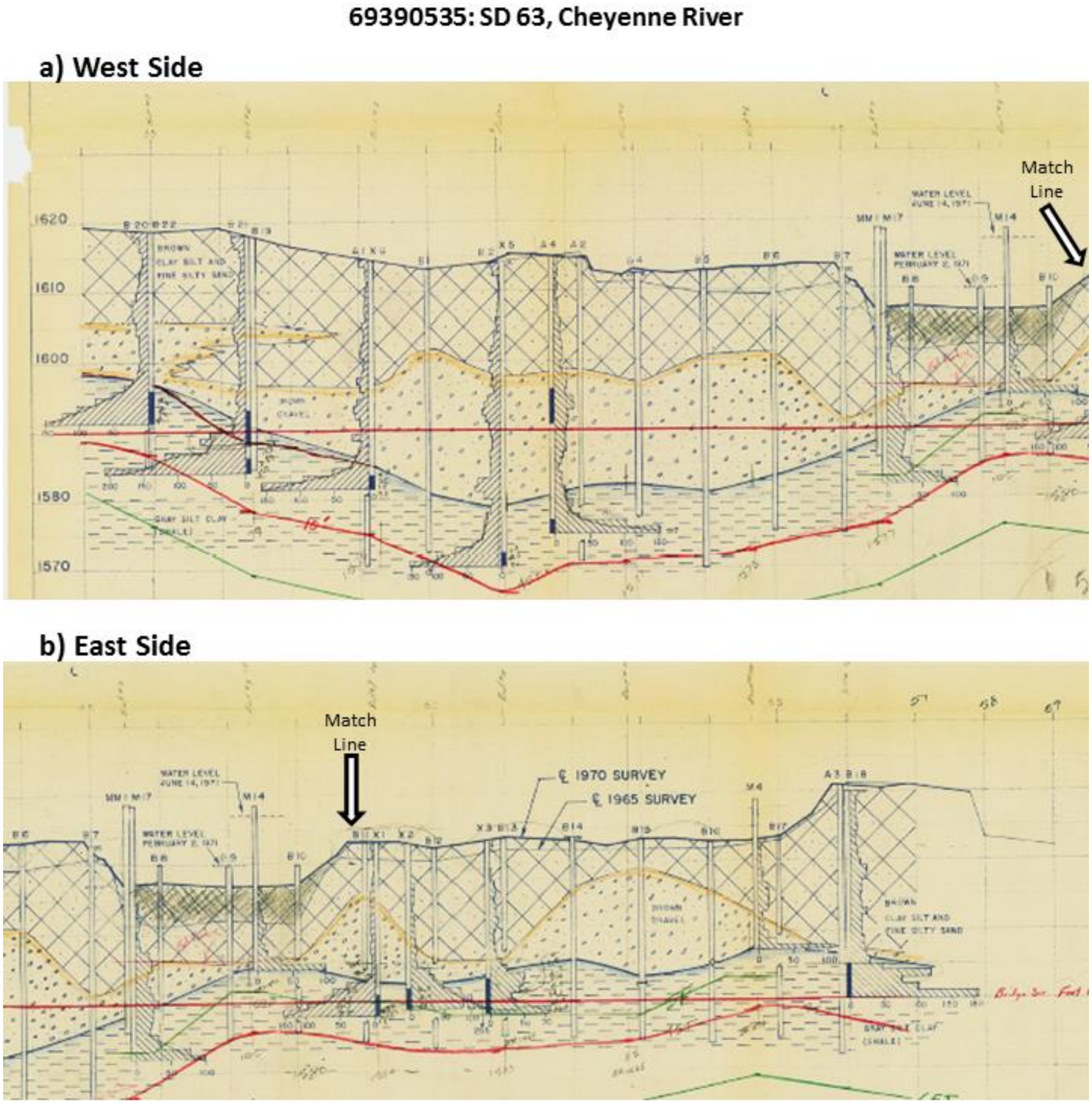
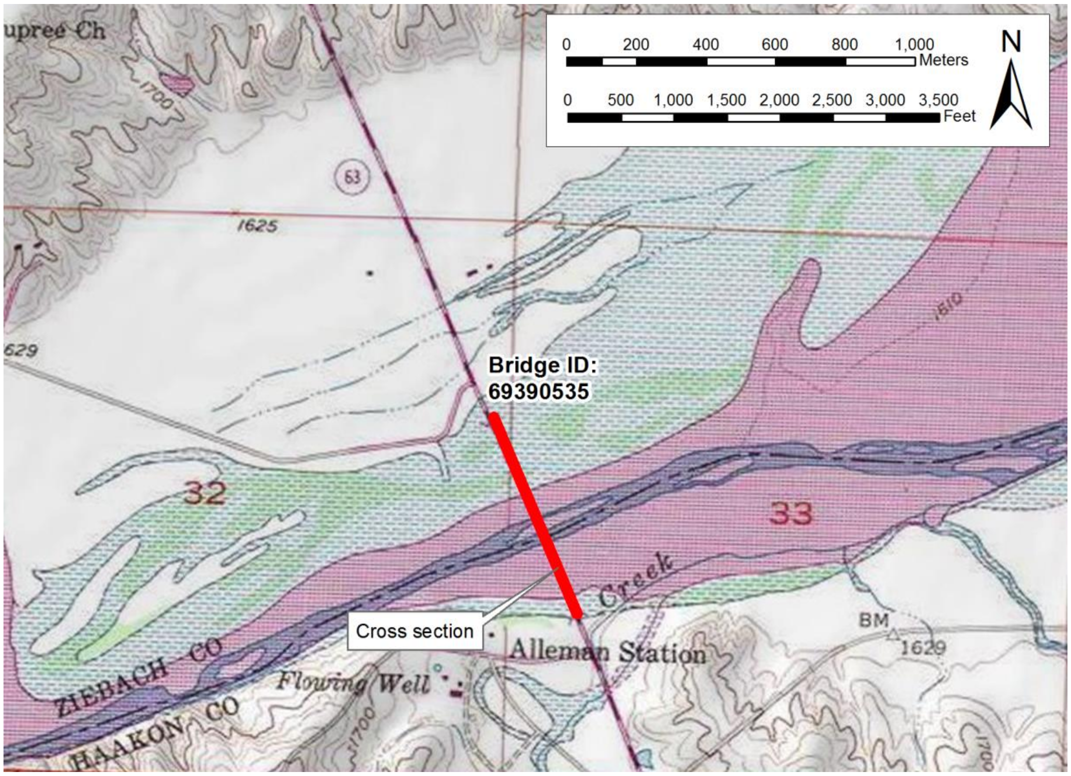


Figure 11. Stratigraphic cross section of valley alluvium at bridge over lower Cheyenne River. Source: SD DOT design plans.



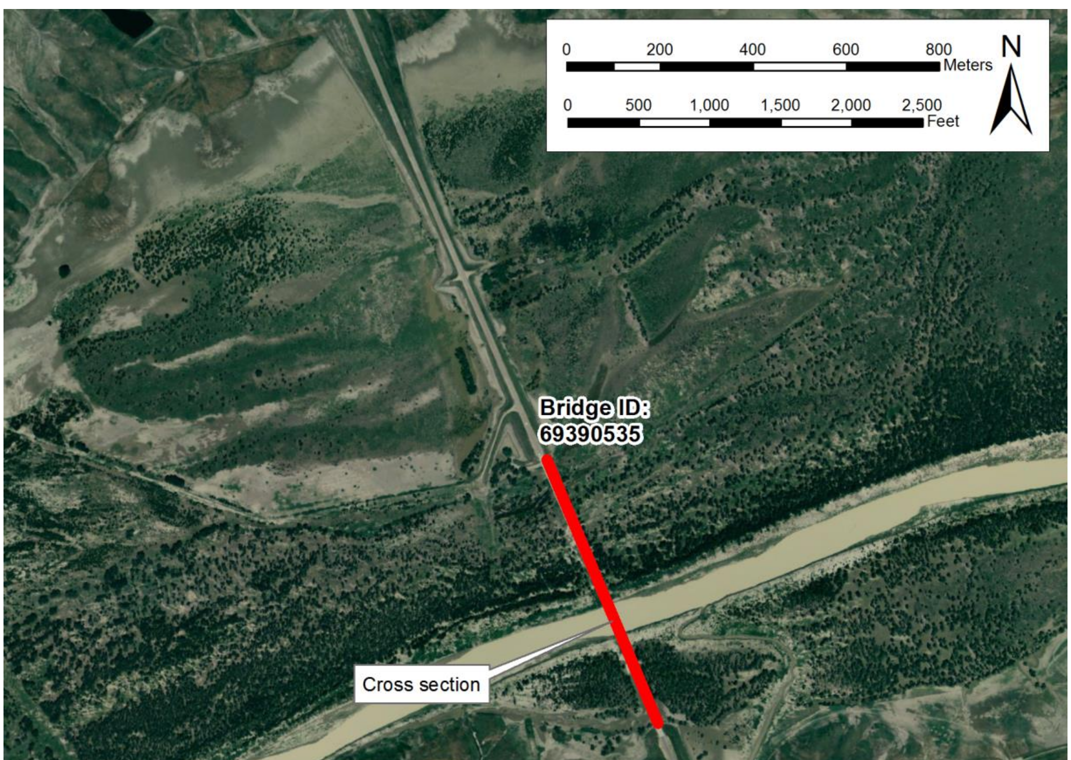


Figure 12. Location of the lower Cheyenne River bridge on USGS quadrangle (upper) and color aerial images (lower).

NRCS Soil Surveys

Much use is made by archaeologists of NRCS soil survey maps, which are available on-line and digitally at 1:24,000 as part of the nationwide Soil Survey Geographic (SSURGO) database program (http://soils.usda.gov/survey/geography/ssurgo/). All geological and geomorphological variables that affect buried site potential are expressed in soil properties. Parent materials influence soil texture. Parent materials, vegetation, climate, relief, and age all influence the differentiation of sediment into the distinct layers, or horizons, of the soil profile. Most of the map units that appear as polygons on NRCS soils maps are labeled with name of a soil series, or a hyphenated pair of series. Series are usually given the name of a nearby town or other well-known place. Examples from South Dakota include the Pierre, Mobridge series. Each series occurs in a defined range of landscapes and landforms, which are identified in the published soils surveys (available on-line at http://soils.usda.gov/survey/printed_surveys/), and in their official series descriptions (OSDs) at http://soils.usda.gov/technical/classification/osd/index.html.

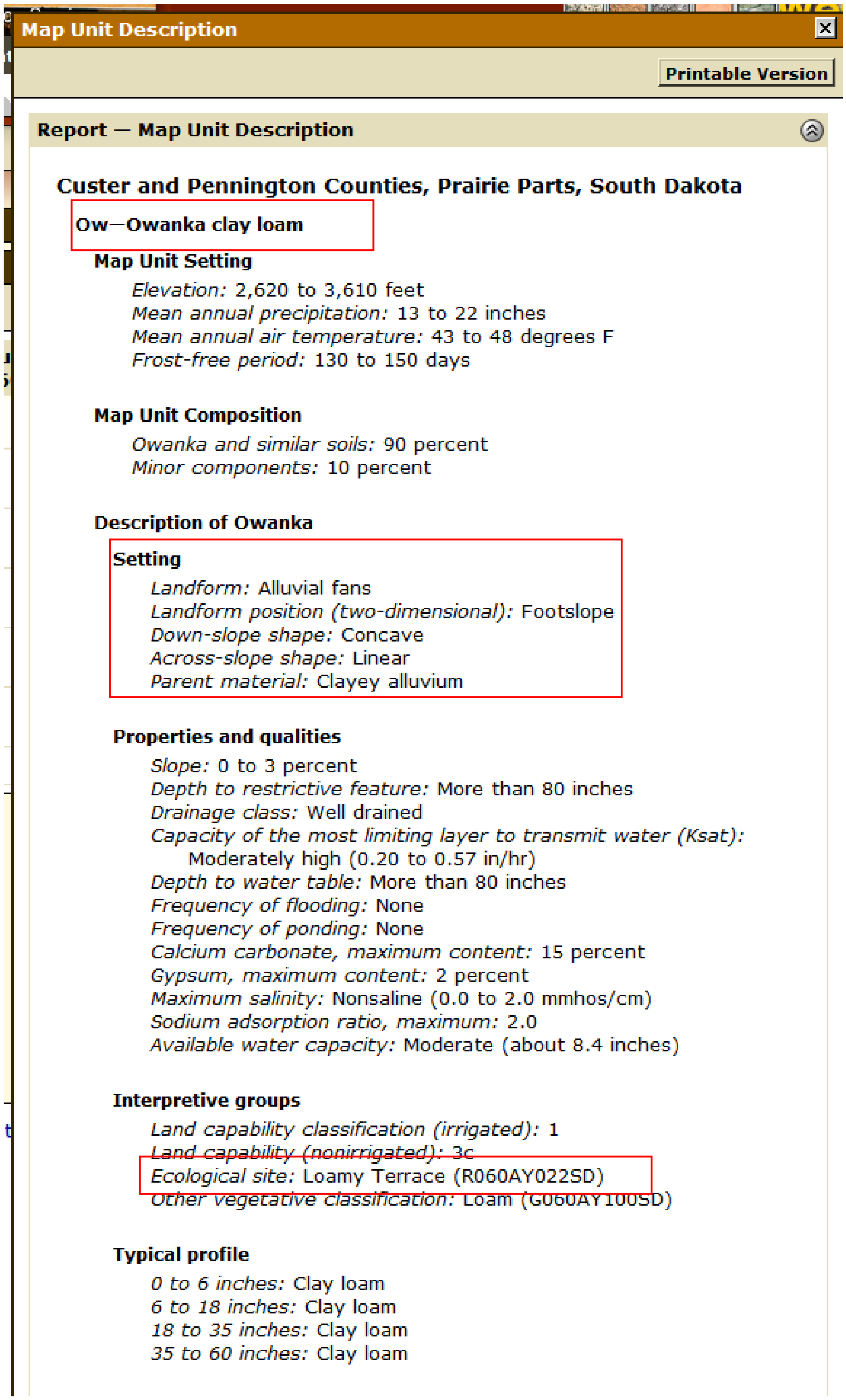
Limitations to the use and interpretation of soil surveys are discussed extensively in publications and on-line. Among the limitations for geoarchaeological interpretation are that soil series defined by the NRCS are described only to a depth of 1.5 m. Holocene-age sediments in valleys, dunes, loess, fans and colluvial slopes are often thicker than that, and buried sites can occur at greater depths. Second, the maps were drawn at a scale of 1:24,000 from aerial photographs, with relatively limited ground truthing. They are not intended to identify the exact kind of soil that will be found at a particular location (e.g., an archaeological site), but only the most likely kind that should occur, as well as other kinds that may be present. Even if a mapping unit carries the name of a single series (e.g., Lowry), NRCS mapping practices permit half or more of the unit to be different series.

These limitations aside, NRCS soils maps can provide a useful, initial indication of buried site potential in an APE, when examined in conjunction with topographic maps and aerial imagery. Valley floors, for example, are well-defined on soils maps as linear networks of relatively narrow soil polygons. In a large valley, narrow bands of soils with steep slopes separating soils with gentle slopes may indicate the presence of a scarp separating two terraces. Polygons that form zones at the foot of, and parallel to valley bluffs are likely to be colluvial slopes and alluvial fans.

The on-line Web Soil Survey (Appendix A) provides quick access to soil survey data about an APE. The website displays a national map with various methods for zooming to an area of interest. Drawing tools are provided to allow the user to draw in the APE of, for example, a Level III survey area. The web site will then display an NRCS soils map with map units labeled, along with tabular data for each map unit. Appendix A provides a step-by-step guide to using the Web Soil Survey.

Figure 13 is an example of the tabular output from an area near the Custer-Pennington county line near Rapid City. The descriptive data, obtained from the SSURGO database, identify properties of the Owanka clay loam map unit, which occurs within the hypothetical project area (Appendix A). The table indicates that the Owanka series typically forms on alluvial fans, in clay loam alluvium. This landform has high potential for buried archaeological sites, and therefore the APE may contain buried sites. Note that the given ecological site, Loamy Terrace, appears to contradict that of the Landform setting. This is because the ecological site is based on criteria in addition to landscape position, and is therefore of less utility for geological interpretation.

Although never the final word in determining buried site potential, the NRCS soil surveys can provide a rapid assessment in advance of an actual field visit. Tools like the Web Soil Survey make the maps available to all users in the same format, facilitating communication, and can be used by all archaeologists regardless of geological background. Those well-grounded in landscape interpretation will be better qualified to interpret the results, and indeed, may prefer to go directly to aerial photographs and other sources.


Map Unit Description

Printable Version

Report — Map Unit Description

Custer and Pennington Counties, Prairie Parts, South Dakota

Ow—Owanka clay loam

Map Unit Setting

Elevation: 2,620 to 3,610 feet
Mean annual precipitation: 13 to 22 inches
Mean annual air temperature: 43 to 48 degrees F
Frost-free period: 130 to 150 days

Map Unit Composition

Owanka and similar soils: 90 percent
Minor components: 10 percent

Description of Owanka

Setting

Landform: Alluvial fans
Landform position (two-dimensional): Footslope
Down-slope shape: Concave
Across-slope shape: Linear
Parent material: Clayey alluvium

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 15 percent
Gypsum, maximum content: 2 percent
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum: 2.0
Available water capacity: Moderate (about 8.4 inches)

Interpretive groups

Land capability classification (irrigated): 1
Land capability (nonirrigated): 3c
Ecological site: Loamy Terrace (R060AY022SD)
Other vegetative classification: Loam (G060AY100SD)

Typical profile

0 to 6 inches: Clay loam
6 to 18 inches: Clay loam
18 to 35 inches: Clay loam
35 to 60 inches: Clay loam

Figure 13. Screen shot from the Web Soil Survey showing landform and parent material information for a map unit in a hypothetical project area that crosses the Pennington-Custer county line. See Appendix A for additional information.

PROJECTS FOR DEEP TESTING

Table 8 is a list of undertakings that this project's volunteer advisory committee identified as commonly requiring Level III surveys. The list is not comprehensive, but illustrates the ranges of area and depth that characterize South Dakota APEs. Undertakings are differentiated in terms of whether their APEs are block-shaped or linear. For testing a block-shaped APE, subsurface tests will usually be deployed on a grid. Corridors are tested with transects parallel to the centerline. The shape of the survey area is also important from a statistical standpoint. Corridors, because of a greater ratio of area to perimeter, have a greater probability of intersecting sites than a block survey (Banning 2002).

The decision to perform deep testing should be made by the agency or in consultation with SHPO. Three considerations should drive the decision:

- Horizontal and vertical dimensions of the APE
- Geological potential of the landform(s) within the APE
- Local and regional archaeological site density.

The horizontal and vertical dimensions of the APE greatly affect the likelihood of finding sites. Table 8 qualitatively rates each project type for the horizontal and vertical impact of its APE. The other two factors being equal, a wide corridor, as for a highway, railroad, or major interstate pipeline, has a greater chance of encountering and adversely impacting buried sites than the Ditch Witched trench for a six inch water pipeline. Likewise, other factors being equal, the probability of finding buried sites increases with increasing vertical depth of the APE.

The chance of finding sites also increases with the increasing density of archaeological sites and the increasing buried site potential of landforms. Buried sites will most often be associated with high potential landforms, and the number of buried sites should be proportional to regional site density. In other words, the more sites that occur in a region, the more sites should be present in subsurface contexts. With low regional site density, the probability of encountering a site by subsurface testing is vanishingly small, to the extent that the cost of subsurface testing will outweigh the risk to cultural resources.

All three factors should be considered concurrently in deciding whether to pursue subsurface testing. A 1 ha undertaking in Pierre Shale-dominated uplands is unlikely to need subsurface testing because the potential for upland silts is low, and regional site density is low. Conversely, an APE of the same size and depth on an MT-2 terrace of the Missouri Trench has a much higher potential to affect buried sites, and needs subsurface testing, because Holocene-age eolian deposits are likely to be present, and site density in these landscapes tends to be high.

Given the added cost of subsurface testing in addition to the surface surveys that are the current practice in South Dakota, it is reasonable to ask at what point an undertaking becomes large enough, in terms of width, depth, and length, to pose a significant risk to buried archaeological sites. At a minimum, the author recommends that deep testing for buried sites be undertaken for undertakings like those in Table 8 with large and deep (>1 m) APEs. The deep testing would occur in landform areas with high or moderate potential for buried sites. From a cost-benefit analysis, low-impact undertakings probably do not warrant the additional costs of subsurface testing of high-moderate potential landforms, unless the undertaking is passing through an area that has a known high potential for significant archaeological deposits, such as a known earth lodge village or an area such as Buffalo Gap with known very high site densities.

Decisions weighing the cost-benefits of buried site testing at Level III should ultimately be based on data currently not available, such as a better understanding of landform-sediment relationships in relation to buried site locations. In addition, statistical analysis or modeling might be undertaken to apply statistical sampling concepts to determining the risk to sites posed by APEs of varying area and depth (e.g., Banning 2002; Kintigh 1988; Krakker et al. 1983; Nance and Ball 1986; Sundstrom 1993;

Table 8. Common Kinds of South Dakota Undertakings and APEs.

Survey Area	Project Type	Area of APE	Maximum Vertical APE < 1m	1-3 m	> 3m
Block	Uranium mining	Large			X
	Borrow Pits	Moderate			X
	Gravel Pits	Moderate			X
	Cell Towers	Small	X		
	Feedlot Lagoons	Small		X	
	Well pads	Small	X?	X?	
Linear	Interstate Pipeline (Keystone XL)	Large			X
	Primary roads	Large			X
	Railroad (DM&E New Build)	Large			X
	Bridges	Moderate			X
	Lewis and Clark pipelines	Moderate		X	
	Secondary roads	Moderate			X
	Electric Lines	Small	X		
	Rural waterlines	Small		X	
	Shelter Belts	Small	X		

Verhagen and Borsboom 2009). An initial step toward a quantitative approach to archaeological site density in South Dakota is presented in Appendix B.

QUALIFICATIONS

Relatively few archaeologists have formal training in the geosciences, just as relatively few geoscientists have formal training in archaeology. Most archaeologists receive their formal education in departments of anthropology, where undergraduate and graduate programs rarely require extensive exposure to the earth sciences. This is changing with the growth of geoarchaeology as a subdiscipline, and with the emergence of Cultural Resource Management degree programs. The fact remains, however, that most field archaeologists develop their earth science skills and knowledge through in-the-field training and experience. Consequently, there is great variability among archaeologists in their ability to recognize and describe soil horizons, sedimentary layers, geomorphological landforms, and other lines of evidence that are important to assessing buried site potential. Perhaps the least developed skillset among archaeologists is that of recognizing and interpreting the geological and pedological processes represented in the sedimentary matrix.

The geosciences and archaeology are broad fields of endeavor. In the following discussion, the terms are restricted in definition: for archaeology, to field survey and excavation (finding and digging prehistoric and historic sites) and, for geosciences, field mapping and subsurface investigation of landforms, sediments, and soils, with specific attention to those of Holocene and latest Pleistocene age.

By Federal standards (36 CFR 61), the minimum qualifications for a professional archaeologist are a graduate degree and one year of full time archaeological experience, including four months in North American archaeology. The guidelines could consider similar criteria for establishing an individual's qualifications as a geoarchaeologist, in terms geoscience education and experience.

For purpose of the South Dakota guidelines, however, the author recommends a focus on applied experience. From this perspective, degree credentials and years of experience are arguably less important than the particular skill sets that individuals have mastered through academic training but perhaps more importantly through field experience. In order of increasing (and cumulative) qualification to evaluate buried site potential, these skill sets are as follows:

1. Skills to map layers in a profile and describe them using standard nomenclature, minimally Munsell color(s), soil texture, inclusions, and site-disturbance features such as rodent burrows. Desired, but not required is the ability to recognize soil horizonation, formal lithostratigraphic units, and erosion surfaces.
2. Skills to recognize significant geomorphological landforms (terraces, colluvial slopes, dunes) in the field and relate them to dominant depositional processes.
3. Skills necessary to interpreting buried site potential from NRCS soil surveys and geological maps, including recognizing parent materials and landforms with potential to contain buried sites, interpreting soil horizonation in terms of relative age and site preservation and habitability potential; understanding the limitations of soils maps for geoarchaeological interpretation.
4. Skills in interpreting aerial and topographic maps to map landforms that represent lateral variation in depositional environments that will be underlain by similar soils and sediments.
5. Skills in describe profiles, cores, and trenches to full NRCS specifications; group strata into lithologic units and facies; and relate them to the landscape elements within which they occur, as well as, and most importantly, the geological and pedological processes by which they formed. .
6. Skills in developing a research design for placing cores, trenches, and other subsurface testing methods to maximize information return for purposes of buried site potential. Included is interpreting the results in terms of chronology and processes of landscape evolution, and make recommendations for subsurface testing.

The above skillsets are listed in ascending order of geosciences knowledge and expertise. Skillsets 1 and 2 are those common to most archaeologists. Skillsets 3, 4, 5, and 6 require increasing levels of formal training or experience in geoarchaeology. With each skill sets, the degree of an individual's specialization in geoarchaeology and/or the geosciences incrementally increases.

In practice, it is generally up to the Principal Investigator to assess the level of expertise his/her team, and to ensure that the person assigned or contracted for a given role is appropriate to their knowledge and skills. Expertise can be evaluated by criteria including but not limited to published works, both graphics and text; curriculum vitae, personal interviews, and on-the-job experience.

PART IV: PRELIMINARY GUIDELINES FOR IDENTIFYING AND EVALUATING BURIED ARCHAEOLOGICAL SITES IN SOUTH DAKOTA

Joe Alan Artz, University of Iowa Office of the State Archaeologist

Prepared for the South Dakota State Historic Preservation Office

9/6//2011

These guidelines were prepared by the University of Iowa Office of the State Archaeologist under the terms of a contract with the South Dakota State Historical Society. They were developed in consultation with the South Dakota State Historic Preservation Office and an advisory committee of archaeologists familiar with the archaeology and geoarchaeology of the state. An initial draft was reviewed by the advisory committee in July 2011, and their comments were incorporated into the document presented here.

The intent of the guidelines is to establish a process that makes a best faith effort to identify archaeological sites that are buried deeper than can be detected by surface survey, cutbank examination, or shallow (<1 m) testing. They are intended to be flexible and realistic for application in South Dakota, but also methodologically rigorous, in keeping with current professional practice in geoarchaeology, and consistent with similar guidelines proposed in other states.

South Dakota survey guidelines (SHPO 2005) establish three levels of survey: Level I, a records search; Level II, a model-based, high/moderate/low probability sampling survey; and Level III, intensive ("100 percent") survey. Most surveys are currently done at Level III (Paige Olson, personal communication 2011). A Level III survey is in many ways inclusive of the other two levels. A records search is required as part of a Level III (SHPO 2005). The Buried Site Guidelines are therefore written for application to Level III surveys, with the understanding that they can be adapted to the needs of Levels I and II. The Guidelines also address post-survey excavations, e.g., testing/evaluation to evaluate NRHP eligibility, and large scale excavations of NRHP- properties.

These Guidelines are intended to supplement the current SHPO (2005) guidelines, which do not explicitly address methods for finding and evaluating buried sites. The sections that follow will not be found in SHPO (2005), but could be incorporated into the text of that document.

Premises

GEOLOGIC PROCESSES

- South Dakota landscapes have been geologically dynamic throughout the Late Pleistocene, Holocene, and historic periods, contemporary with human occupation of the region.
- Geologic processes have acted throughout this time to erode and bury archaeological sites. These processes have both preserved and destroyed archaeological deposits.
- Geologic processes can be broadly grouped according to their potential effects on archaeological sites.
- The same groups of processes are active in forming the landscape.

Therefore, landforms that comprise the landscape can be evaluated in terms of their potential for the burial and erosion of archaeological deposits.

EVIDENCE FOR GEOLOGIC PROCESSES

- Landscape processes active within a site or survey area can be identified from geomorphic factors such as slope, hydrology, and erodibility of available geologic materials.

- Landscape processes active within a site or survey area can also be identified in data obtained by subsurface testing, including lithology (sediments), pedology (soil horizons), stratigraphic contacts, and relative or absolute age.
- Stratigraphy, defined as vertical and horizontal relationships of strata identified in the subsurface, provides data on changes through time and across space in geologic processes that could act to erode or bury archaeological deposits.

Therefore, the potential for intact archaeological deposits can be inferred from geomorphological and stratigraphic data, and be used to determine the potential for deposits to be present, and to evaluate the integrity of deposits that are encountered.

SITE, ARTIFACT, AND FEATURE DENSITY

- Archaeological sites vary in number and density (site area per unit land area) across South Dakota.
- The detectability of buried sites is a function of size, density of artifacts/features, and testing methods.
- The potential for an effect / no adverse effect on a buried site is a function of the horizontal and vertical dimensions of the undertaking.
- For sites of a given artifact density and size, the potential for adverse effects decreases with the foot print and depth of impact of the undertaking.
    - the chances that a 4” diameter water line or utility pole will encounter and disturb artifacts and features is small, and therefore the risk of adversely effecting a buried site is negligible.
    - Aerially extensive and deeply excavated projects such as roads, bridges, major pipelines, and quarries pose a greater risk to archaeological sites.

Therefore, potential site/artifact/feature density and the 3D footprint of the undertaking are factors that can be considered in determining the need for Level III subsurface testing

BURIED SITE POTENTIAL

Three categories of buried site potential are defined in terms of geological indicators and their archaeological implications. The geologic indicators are observable in soils, sediments, and stratigraphy beneath the surface, and are used to evaluate if sediments were laid down in an environment conducive to the burial and subsequent preservation of archaeological deposits. The archaeological implications involve field methods that are necessary to do the evaluation, and to determine the appropriate depth of subsurface testing.

High Buried Site Potential

Geological Indicators

Low-energy depositional processes are dominant, yielding strata that are:

- conducive to preserving buried archaeological deposits in primary context, with stratigraphic integrity, and
- thick enough to have the potential for stratigraphic separation of archaeological components, either in vertically-stacked buried soils, or in environments with high sedimentation rates.

Buried soils are diagnostic, but do not need to be present for buried sites to occur. If present, buried soils provide stratigraphic markers for tracing occupation surfaces laterally, and are good indicators of episodic deposition, stable surfaces, and potential for stratigraphic separation of components, all of which can contribute to the National Register eligibility of a buried site.

Archaeological Implications

If buried deeper than 50-100 cm, subsurface testing is necessary to detect and determine the boundaries of archaeological deposits. Archaeological deposits within 50-100 cm of the surface can be discovered by near-surface methods like shovel and auger testing. They may also be exposed at the surface by rodent burrowing, erosion rills/gullies, tree throw, frost heaving, and similar processes. For cultural deposits discovered in cutbanks or other sediment exposures, subsurface testing may still be necessary to determine their lateral extent.

Moderate Buried Site Potential

Geological Indicators

Depositional processes yield stratigraphic sequences that are

- conducive to preserving buried sites, but
- have been modified by high energy or erosional processes such as deflation, channel cut-and-fill, or mass-wasting that have reduced the possibility that intact archaeological deposits are preserved.

Buried soils, if present, will be weakly developed and thin. Sedimentary deposits with moderate potential will exhibit both lateral and vertical variability in stratification, indicative of fluctuations between high and low energy deposition, and/or deposition and erosion.

Archaeological Implications

Cutbank exposures or aerial imagery interpretation may sometimes be sufficient to determine that the APE has been subject to fluctuating energy regimes. In other cases, such evidence is only present in the subsurface and can be detected by surface testing. In moderate potential sedimentary deposits, subsurface investigation might focus on detecting “pockets” of low energy sediments and, if found, testing them for the presence of archaeological deposits. In some cases, high potential deposits may overlie or underlie moderate potential ones, or transition laterally from one to the other.

Low Buried Site Potential

Geological Indicators

Sediments are either:

- too old or too thin to contain buried archaeological deposits in primary context with stratigraphic integrity, or
- accumulated in high-energy depositional environments such as stream beds or debris flows where both habitability and preservation would be unlikely.

Low potential is inherent in erosional landscapes characterized by steep slopes, erodible parent materials, and thin mantles of sediment over bedrock, till, or outwash. Soil development will be very weak or absent due the lack of land surface stability. High energy transport environments are characterized by sandy and gravelly textures, or interbedded gravels, sands, silts, and clays that were deposited within stream channel, in sand or gravel bars within the active channel belt, or debris flows.

Archaeological Implications

No subsurface testing is needed in low potential environments. Cutbank exposures, aerial imagery, surface evidence of severe erosion may be sufficient to determine the age, thickness, and energy regime of the APE. In other cases, such evidence is not detectable at the surface but can be identified by subsurface testing. Particularly in alluvial environments, low potential, high-energy channel deposits will often underlie a low-energy, high potential environment. In rockshelters, roof fall (high energy) may cover lower-energy deposits containing archaeological deposits.

SEDIMENTARY ENVIRONMENTS AND LANDFORMS

A landscape is a mosaic of landforms underlain by sediments deposited in different sedimentary environments. The table below lists the major sedimentary environments and landform types for late Wisconsinan and Holocene deposits in South Dakota. The dominant geological processes associated with each environment and landform influence potential for the presence and preservation of buried archaeological deposits. For detailed information on landforms and geological processes see Waters, 1992, *Principles of Geoarchaeology: A North American Perspective.* University of Arizona Press, Tucson.

Sedimentary Environment	**Landform**	**Buried Site Potential**	**Processes**
Eolian Environments	Dunes	high	eolian
	Interdunal wetlands, lakes	low to mod	lacustrine, eolian
	Interdunal flats, blowouts	low	Erosional: wind deflation
	Sand sheets	mod	eolian
	Loess sheets	mod	eolian
	Cliff dunes, lip loess	high	eolian
	Playas	high	lacustrine, eolian
Alluvial Environments	Levees, floodbasins, alluvial ridges (top stratum, vertical accretion)	high	low energy fluvial
	Channels and bars (bottom stratum, lateral accretion)	low	high energy fluvial
	Terraces	high	high grading upward to low energy fluvial.
	Floodplain	low (for prehistoric)	Historic period vertical and lateral accretion
	Terrace veneer	mod	low energy fluvial
	Canyons	high	fluvial, colluvial
	Low order valleys	mod	fluvial, colluvial
	Sod tables	high	fluvial, colluvial, eolian
Valley Margin Environments	Colluvial slopes	mod to high	colluvial, mud/debris flow
	Alluvial fans	high	fluvial, debris/mud flow
Mass-Wasting Environments	Debris, Mud flows	low	mud flow, landslide, slumping
	Slumps	high to low	mud/debris flow, landslide, slumping
	Talus slopes	low	mud/debris flow, slumping
Rockshelter/Cave		high to mod	solution, wind abrasion, rockfall, colluvial, alluvial
Glaciofluvial/Glacio-lacustrine	Outwash terraces, shallow to gravel	low to mod	glaciofluvial, eolian, fluvial
	Glacial lake plains	low	lacustrine, alluvial, eolian
	Beach ridges	mod	shoreline
Erosion-Dominant Uplands	Glaciated uplands	low	hillslope processes, headward incision of streams, mass wasting, eolian deflation; lake bed sedimentation
	Unglaciated uplands	low	hillslope processes, headward incision of streams, mass wasting, eolian deflation
	Mountains	low	slope processes, headward incision of streams, mass wasting

QUALIFICATIONS

By Federal standards (36 CFR 61), the minimum qualifications for a professional archaeologist are a graduate degree and one year of full time archaeological experience, including four months in North American archaeology. The guidelines could consider similar criteria for establishing an individual's qualifications as a geoarchaeologist, in terms geoscience education and experience.

For practical application, however, degree credentials and years of experience are arguably less important than the particular skill sets that individuals have acquired, either through academic training or experience. The following skill sets are identified, listed in order of increasing and cumulative qualification to conduct a geoarchaeological assessment of complex landscapes evaluate buried site potential.

1. Map layers in a profile and describe using standard nomenclature, minimally Munsell color(s), soil texture, inclusions, and krotovina. Desired, but not required: recognizing soil horizonation, formal lithostratigraphic units, and erosion surfaces.
2. Recognize significant geomorphological landforms in the field and relate them to dominant depositional processes.
3. Interpret buried site potential from NRCS soil surveys, including recognizing parent materials and landforms with potential to contain buried sites, interpreting soil horizonation in terms of relative age and site preservation and habitability potential; understanding the limitations of soils maps for geoarchaeological interpretation.
4. Interpret aerial photographs and topographic maps to map landforms that represent lateral variation in depositional environments, and will be underlain by similar soils and sediments in similar deposition.
5. Describe profiles, cores, and trenches to full NRCS specifications; group strata into lithologic units and facies; and relate them to the landscape elements within which they occur.
6. Develop a research design for placing cores and trenches to maximize information return for purposes of buried site potential; interpret results in terms of chronology and processes of landscape evolution, and make recommendations for subsurface testing.

The above skill sets are list in ascending order of geosciences knowledge and expertise. Bullets 1 and 2 are skill sets common to most archaeologists. Skill sets 3, 4 and 5 require increasing levels of formal training or experience in geoarchaeology. Many, if not most, archaeologists consult NRCS soil surveys, but geoscience expertise increases the information the archaeologist can extract from them.

The Principal Investigator is responsible for assessing the level of expertise of his/her team, and is responsible for ensuring that a crew or team member's role is appropriate to the skillsets in which they have demonstrated expertise. Expertise can be evaluated by criteria including but not limited to published works, both graphics and text; curriculum vitae, personal interviews, and on-the-job experience.

Identifying and Evaluating Buried Site Potential and Buried Sites

DESKTOP ASSESSMENT

The desktop assessment (DA) is conducted along with the records search. The records search identifies and reviews previously recorded sites within a 1 mile radius of the APE (SHPO 2005). Similarly, the purpose of the DA is to identify landforms within the APE and evaluate their buried site potential. The DA is a preliminary, nonbinding estimate of buried site potential that does not require, but is verifiable by fieldwork.

The DA is recommended for projects subject to SHPO review, depending on the size and depth of the APE and its location in the landscape. This calls for locating the APE in relation to topography as mapped on a USGS 1:24,000 quad and an NRCS soils map, and obtaining information on the soil mapping units within the APE.

The USGS quad map is already needed for letter and full survey reports (SHPO 2005). Minimally, the NRCS soils map should be one downloaded from the NRCS Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx; Appendix A). In addition to the map, provide the tabular information on each mapped soil within the APE, including parent material and landform. Tabular data downloaded from the Web Soil Survey is an acceptable and recommended format. Use of the Web Soil Survey is documented in Appendix A.

The DA may also include maps and imagery that delimit landscapes and landforms from other sources, including but not limited to aerial imagery maps obtained from sources such as Google Earth, Bing Maps, and the USGS Earth Explorer.

A more detailed, extended DA can be completed, prior to fieldwork, for undertakings that have large impacts (e.g., roads, interstate pipelines) or are located in geologically complex settings (e.g., major river valleys). For such undertakings, the minimal requirements set forth above cannot provide adequate information for survey planning purposes. The DA should therefore minimally include a surface geology map of landforms drawn on a base map of high resolution aerial photographs, and interpreted in terms of the geologic processes that were most likely involved in the development of the landscape, and the potential burial or erosion of sites, within the APE. Surficial geological maps may also be consulted. LiDAR imagery or close interval contour maps, if available for the APE, should be consulted. Historic maps are often useful for showing former river channel (e.g., Brakenridge and McReady 1988), which can help to identify very young or intensively channeled landforms with little archaeological potential. If geotechnical borings have been made for engineering purposes, the stratigraphic logs of bore holes may provide information on subsurface stratigraphy. The map(s) and interpretations made by the Extended DA are preliminary, but verifiable by fieldwork.

GEOARCHAEOLOGICAL ASSESSMENT

In landforms with moderate to high buried site potential, a Geoarchaeological Assessment (GA) and an Archaeological Assessment (AA) should be conducted. The purpose of the GA is to determine the thickness and lateral extent, within the APE, of soils and sediments with moderate to high potential, and recommend locations within the APE where intact archaeological deposits are likely to be preserved. The purpose of the AA (discussed below) is to search for buried archaeological deposits in high potential depositional contexts. The GA can be conducted separately or simultaneously with the Archaeological Assessment (AA). If conducted separately, the GA should be done prior to the AA. A separate GA prior to survey is recommended for large and deep APEs, or where geologically complex stratigraphy is anticipated.

The GA identifies and maps the landforms that are present in the APE, and does sufficient subsurface examination to document the stratigraphic sequence, soils, and lateral variability of deposits that underlie each landform. The GA also documents the lateral extent and range of deposits with buried site potential, so that the AA can focus on areas of the APE that maximize, for example, the stratigraphic separation of components, or in the best-drained, least flood prone areas where artifact and feature density might be higher. Subsurface tests for the GA should be carried to the vertical depth of the APE, or into “base sediments,” which ever is encountered first. “Base sediments” are defined as deposits too old to contain archaeological sites (e.g., glacial till, bedrock), or depositional environments not conducive to habitation or site preservation (e.g., gravel-and-boulder talus or colluvium, high energy, in-channel sands and gravels, or outwash).

The method used for subsurface examination must be capable of reaching the vertical extent of the APE or the contact with base sediments. Backhoe trenching, coring, bucket augers, cutbank examinations, and certain kinds of remote sensing (GPR, resistivity, electromagnetic induction) can be used alone or in combination to obtain the needed information. In general, shovel testing and similar methods, because of the shallow depths attainable, are not an acceptable method for a GA.

The GA results in a detailed, ground-truthed map of landforms in the APE, and documents the thickness and lateral extent of deposits with buried site potential.

The GA can be conducted concurrently with the subsurface archaeological survey, especially in landscapes that are depositionally simple (horizontally-layered strata that are not expected to change appreciably over the APE), or where extensive cutbanks provide adequate exposures to assess the subsurface geology of the APE.

In depositionally complex landscapes, or for large, high impact APEs, the GA should be done in advance of the subsurface archaeological survey. In these cases, information on the lateral extent and thickness of deposits with buried site potential should be used to plan the deployment of archaeological testing to maximize the chance of discovering buried sites.

If a professional geoarchaeologist is not specifically called for in the Agency's request for proposal, the Principal Investigator is responsible for determining whether the added expertise of a professional geoscientist or geoarchaeologist is needed for the GA.

ARCHAEOLOGICAL ASSESSMENT

The AA, simply stated, carries the surface survey for sites into the subsurface. In contrast to the GA, which simply determines the potential for buried sites, the AA seeks to actually discover sites. The AA must extend to the vertical extent of the APE, or to a contact with base sediments, whichever is encountered first. Any tool or excavation method capable of reaching the appropriate depth is acceptable, provided it can identify archaeological sites. Soil cores are not acceptable for the AA because of their small (0.75-3 in) diameter, nor is shovel testing, because of limited depth. Test units are acceptable if excavated to OSHA standards. The recommended methods are backhoe trenching or 20-cm-diameter auger tests.

If subsurface testing is done with augers or a similar method, excavated soil must be screened. If done with backhoe trenching, machine excavation should proceed in horizontal slices not greater than 5 cm thick, with excavation observed by an archaeologist. Another archaeologist should constantly monitor back dirt piles for artifacts. If a trench can be safely entered in compliance with OSHA standards, the walls should be shovel scraped or troweled for artifacts and features.

Stratigraphy exposed in all tests and trenches should be described. Minimally, the description should include Munsell color, soil texture, percent redoximorphic features ("mottles"), gravel content, and carbonate stage. A full description is recommended, including the minimal observations in addition to features such as soil structure, cutans (coatings on clay surfaces), and other properties as specified in NRCS terminology (Schoeneberger et al. 2002).

If a professional geoarchaeologist is not specifically called for in the Agency's request for proposal, the Principal Investigator is responsible for determining whether the added expertise of a professional geoscientist or geoarchaeologist is needed for the AA.

SUBSURFACE SITE EVALUATION

Sites identified by surface survey on landforms with moderate to high buried site potential should be tested to document their depth and stratigraphic integrity. If near surface shovel tests or similar methods, penetrating to 50-100 cm, cannot reach a base stratum within the vertical APE, large diameter (e.g.,

>=20 cm) augering, trenching, or test units should be excavated to test for buried cultural material. Test units and trenching should be excavated in compliance with OSHA regulations. Subsurface tests should be placed on grids or transects, and should be spaced at intervals sufficient to intersect an archaeological site, if present. Test grids or transects should extend to or beyond the horizontal extent of the surface visible site, or beyond the limit of subsurface archaeological deposits, if present. For sites exposed in cutbanks, subsurface testing using the above methods should be extended at a right angle to the cutbank exposure to determine the depth, stratigraphic integrity, and artifact content of associated archaeological deposits

EVALUATION AND MITIGATION

The purpose and methods for geoarchaeological work during post-survey excavations are similar to those for Level III survey, but are focused on geomorphology and stratigraphy of sites rather than survey areas. Geoarchaeological work will likely focus on tracing the lateral extent of sedimentary deposits to allow reconstruction of site paleotopography, and to determine the lateral extent of strata with high buried site potential The methods used are at the discretion of the Principal Investigator, but should be justifiable to SHPO. Drill rig or manual coring and/or trenching are the recommended methods. A preliminary phase of geoarchaeological investigation by trenching or coring is recommended to determine the lateral extent of cultural deposits or high potential sediment deposits, so that excavation units can be placed in locations that maximize, for example, the stratigraphic separation of components, or in the best-drained, least flood prone areas where artifact and feature density might be higher.

In addition, the geoarchaeological part of evaluation and mitigation excavation projects also include the mapping and description of excavation profiles, and the definition and interpretation of natural features encountered in archaeological excavations. A preliminary phase of geoarchaeological investigation by trenching or coring is recommended to determine the lateral extent of cultural deposits and high potential sediment deposits, and to assist in planning the deployment of excavation units.

REPORT DOCUMENTATION

Results of DA's and GA's should be incorporated into letter reports and full reports according to SHPO guidelines (SHPO 2005). Letter reports, used primarily for documenting negative-result surveys, should include the results of the DA and minimally include an NRCS soils map and NRCS tabular data, as described above, in addition to the already-required USGS 7.5 minute topographic map. If a GA and AA were undertaken, these should be incorporated into the methods and statement of findings called for in Sections 7-8 of the letter report guidelines (SHPO 2005).

In addition to the content specified by SHPO (2005), full reports should specify the vertical extent (depth of impact) of the APE in the introduction, and the results of the DA under Background Research. The survey methods and results section(s) should present methods used in the GA and AA and the results of the GA in terms of landforms, stratigraphy, soils, and landscape process interpretation. The results section should also detail the horizontal and vertical boundaries of each identified sites and discussion of site-specific landform, stratigraphic, and pedologic contexts. Finally, full reports should include profile descriptions of all profiles recorded in the GA and AA. These can be presented in the results section, or in an appendix.

PART V: CONCLUSIONS

Summary

The purpose of this report has been to review the geoarchaeology of South Dakota, and to develop guidelines that set forth a methodology for identifying and evaluating buried archaeological deposits in the state. The factors considered in developing the guidelines can be summarized in the following list. The first two factors provide the geoarchaeological basis for applying the guidelines. These were the focus of Part I, the geoarchaeological overview. The next three factors are considerations involved in applying guidelines, and were the primary focus of Part II.

1. It is necessary to know which sedimentary environments have the greatest buried site potential.
2. It is necessary to know the landforms and landscapes in which these sedimentary environments occur.
3. It is necessary to know whether an undertaking poses a significant risk to buried cultural resources.
4. It is necessary to determine whether the geoarchaeological assessment of buried site potential in an APE will occur before, or as part of, the Level III assessment to find sites.
5. It is necessary to determine what geoarchaeological methods and tools will be used for the geoarchaeological and archaeological assessments.

These four factors can be translated into practical, case by case, “boots-on-the-ground” assessments of buried site potential as follows.

LANDFORMS AND SEDIMENTARY ENVIRONMENTS

Factors 1 and 2 are based on considerations of the three classes of buried site potential identified in Table 7, and the landscapes, landforms, and sedimentary environments identified in Tables 4-5. As used in the guidelines, buried site potential is qualitative, not quantitative. Low, moderate, and high do not translate, and should not be translated, into probabilities of whether or not a buried site will actually exist. Low, moderate, and high buried site potential refer solely to the geological processes that have created the sedimentary record contained in the vertical APE. These processes are discussed in the last section of Part III. The geoarchaeological concept of buried site potential presented in this report and in the guidelines is consistent with that applied in the field during every Level III survey. An archaeological walking in transects are constantly evaluating whether or not the landscape setting is the kind of place one would expect to find an archaeological sites. Steep Pierre shale slopes are quickly climbed to reach the level ridge top where the crew slows down. Surveying a valley floor, a crew checks the cutbanks because they realize that buried sites may be found there. On uplands, where all archaeologists known that buried sites are sometimes found, the crew will check out blow outs, cattle trails, ditch cuts, prairie dog burrows, and any other disturbance that promises a glimpse of the subsurface. The concepts presented in this report and the guidelines extend these established practices to depths greater than those visible from the surface, shallow subsurface testing, and cutbank inspection. Evaluating an APE for deeply buried site potential (Table 7) requires revised and different methods and approaches to survey and evaluation.

However, from a boots-on-the-ground perspective, as made clear in Table 7, deep testing for archaeological deposits is only necessary in landforms where geological conditions are right for the formation (by human occupation) and preservation of such deposits. Those landforms are listed in Tables 4-5. This list is probably not complete. Some environments, such as sinkholes and spring-related deposits are not included. The list of processes for each environment is greatly simplified. However, Tables 4-5 are sufficiently comprehensive for purposes of applying the guidelines to the survey and evaluation of specific APEs.

Table 5 lists ca. 25 landform or landform mosaics, most of which have buried site potential. However, the "Erosion Dominant" mountain and upland landscapes, as well as the primarily low potential glaciofluvial and glaciolacustrine environments, occupy far and away the greatest portion of South Dakota's land surface (Figure 6). The deep testing guidelines presented here do not apply to these landscapes, except in level terrain where thick, Holocene-age eolian deposits are present. Dune fields, loess-sheets, sand-sheets, cliff-top ("lip") eolian deposits are among these, and can be quite extensive. NRCS-mapped soils provide a tentative basis for locating some but not all such deposits. Missouri Trench and West River soil series commonly associated with Oahe Formation eolian deposits include Lowry and Sully. In the Grand-Moreau region, however, McFaul identified the Oahe Formation at archaeological sites where the NRCS-mapped soils make no mention of eolian parent materials or landforms. As discussed in the geoarchaeological overview of the Sandstone Butte Region in Part II, Albanese identified local colluvium as the dominant sediment environment encasing buried upland sites. Sediments at these sites can be correlated with the Oahe Formation on the basis of soil stratigraphy (e.g., Thompson and Leonard paleosols). As Coogan (1987) found along the Missouri Trench, the Oahe Formation is more than simply eolian in origin, as initial descriptions (Clayton et al. 1976; Coogan and Irving 1959) suggested, or as subsequent workers have interpreted. Applying the guidelines, however, especially during Level III, will rarely need to consider these complexities. From a boots-on-the-ground perspective, what needs to be determined is whether a Holocene-age sediment mantle is present, and whether it is conducive to preservation. These judgments may be difficult to make, especially at Level III. A workable rule of thumb, however, might be that the presence of buried A horizons would be a certain indicator that the APE contains high potential for buried sites, to which the guidelines apply.

Within landforms and sedimentary environments with potential for preserved archaeological deposits, potential often if not always varies both horizontally and vertically across the landscape and within an APE. Alluvial fills underlying Holocene terraces are a good example. As discussed in Part III, alluvial sediments are often characterized by sandy to gravelly channel sediments at the base of the sequence that grade upward into fine-textured (clay to fine sand) overbank deposits. The bridge-design cross sections shown in Figures 9-11 have examples of the differentiation of these top- and bottom-stratum deposits. In alluvial sedimentary environments, for purposes of the guidelines, only the top-stratum sediments should be considered to have high archaeological potential, and therefore deep testing for archaeological deposits need occur only in depth intervals of the APE where the top stratum occurs. From an in-the-field perspective, this often means that testing can stop when textures coarser than fine sand are encountered. This is a tremendous oversimplification of the sedimentary record, but the author has found it a useful rule-of-thumb for archaeological crews to follow in the field.

METHODOLOGY

In the list presented above, Factors 3 and 5 involve decisions about if, where, and when deep testing to identify and evaluate buried sites is undertaken. The guidelines begin with a desktop archaeological assessment that identifies the landforms and suggests the sedimentary environments that may be present within the APE. An initial, but tentative determination can be made from low-resolution sources such as county- or quadrangle-scale geological maps or NRCS soils maps (e.g., Appendix A). The guidelines recommend use of the NRCS web soil survey as a quick way to perform a DA. Although its results should always be considered inconclusive, for many small areas and/or shallow-impact undertakings, a determination based on NRCS soil mapping may be sufficient to determine that an APE (given its dimensions, depth, and regional site density) poses a sufficiently low risk to sites, if present, that additional steps under the guidelines are not warranted. Criteria for considering the risk of undertakings at varying spatial scales are outlined in Table 8.

The guidelines recommend the NRCS Web Soil Survey (Appendix A) as the best method for doing an NRCS-based DA. After an initial learning curve, the web interface is easy to use, especially when compared to attempting to extract and compile the same data from published soil surveys in book or pdf form. Very large areas, sufficient for survey areas covering many hectares or linear kilometers can be quickly digitized, and the map and tabular data downloaded. Detailed tabular data (e.g., Figure 13) might only be necessary for map units that include high potential landforms (Tables 4-5). The output (Appendix A, Step 7; Figure 13) are not entirely compliant with archaeological graphic conventions, but in the author's opinion would be acceptable, especially in a short- or letter-report format.

Reliable landform mapping, however, should be based on high resolution aerial imagery, topographic contours, and/or other sources. This form of mapping is strongly recommended for DAs of large-area and/or deep-impact undertakings (Table 8), especially in areas that are depositionally complex or have high site density. Soil maps, geotechnical borings, and existing knowledge from previous studies can provide a basis for suggesting the depth and thickness of Holocene-age sediments with buried site potential. However, conclusive identification can only be accomplished with field work in the form of the GA and AA set forth in the guidelines

For large APEs that intersect complex depositional sequences, such as valley floors with multiple intersecting terraces and meanderbelts, the author would recommend that the GA should be done first, with the results used to develop a research design for Level III AA. In less complex settings, the GA (to identify and map sedimentary environments with high, moderate and low potential), and the AA (to search for sites in the high and moderate potential areas) will often occur at the same time. The qualifications section of the guidelines allow principal investigators the flexibility to assess the "boots-on-the-ground" skill sets needed to conduct the deep testing, and building a team that possesses those skills.

A final boots-on-the-ground decision in applying the guidelines is deciding what tools will be used to do deep testing to identify and evaluate buried site potential. Based on his experience, and a review of existing deep testing practices in other states, the author recommends that backhoes or drill rigs be used for GAs to determine buried site potential. An alternative, more time- and labor-intensive, would be to use augers with extensions capable of penetrating to the bottom of the APE, or to low potential sedimentary environments, whichever is encountered first. Shovel tests, power augers, and other shallow testing methods are never sufficient to evaluate deeply buried site potential. For the AA (finding sites) the author recommends backhoe trenching, posthole augers, or flight augers, or a combination of both.

WHEN TO APPLY THE GUIDELINES

The author strongly recommends that the guidelines be applied as part of Level III intensive surveys for cultural resources, as is common practice in other states with explicit deep testing guidelines (Table 6). An alternative, raised within the committee, would be to only apply the guidelines (i.e., do deep testing) in the post-survey, evaluation phases of work. Although perhaps more consistent with current practice in South Dakota, the author does not recommend this approach because deeply buried sites would only be discovered if they have a surface-visible component, which not all buried sites do. Such sites will either be lost, or discovered during construction. The former is less than satisfactory from a Section 106 perspective, and the latter can result in delays and added costs.

There was consensus among the project advisory committee that the guidelines, and in particular the GA and AA, should not be applied across the board to all undertakings. However, there was not a consensus on where, in the continuum of undertakings (Table 8), the decision to apply versus not apply the guidelines should be set. On this point, the consensus of the committee was that the guidelines need to be flexible because many considerations contribute to such decisions.

There was a strong consensus among the project advisory committee that the scale of the undertaking (e.g., the dimensions and depth of the APE; Table 8) should be taken into account when determining the need to apply the guidelines. Undertakings covering large areas and deep impacts have a greater probability of encountering sites, and subsurface testing of moderate-to-high potential sediments in the APEs of such undertakings would seem warranted. On the other end of the spectrum, are small-area, shallow-impact undertakings such as narrow diameter pipelines that have a low probability of intersecting deeply buried sites, unless in a locality where site density, and artifact and feature density within sites, is high. There was consensus within the committee that such undertakings pose little risk to the archaeological record, and that the guidelines need not apply to a large majority of these undertakings. Between these two examples is a continuum of undertakings with variable sizes and depths. In practice, hard-and-fast rules will be hard, and perhaps inadvisable, to define and apply. It is likely that for all but the largest and smallest projects, decisions concerning when to apply the guidelines will be made on a case by case basis, taking into consideration a) the area and depth of the APE; b) the presence and proportion of high to moderate potential sediments in the APE; and c) local and regional site density.

A third step in the process of applying the guidelines will be to determine when the geoarchaeological assessment should take place. For large APEs that intersect complex depositional sequences, such as valley floors with multiple intersecting terraces and meanderbelts, the geoarchaeological assessment should be done first, with the results used to develop a research design for Level III subsurface testing. In less complex settings, the geoarchaeological assessment (to identify and map sedimentary environments with high, moderate and low potential), and the archaeological assessment (to search for sites in the high and moderate potential areas) may, and in practice often may occur at the same time.

Recommendations

This report has evaluated the state of current knowledge of South Dakota geoarchaeology, and assessed survey and evaluation practices currently used in the state from the perspective of practices elsewhere in the nation, and also from the perspective of the geoarchaeological realities of where, and how deeply, archaeological deposits can occur in the state. On this basis, guidelines for deep testing were developed to assist the South Dakota SHPO establish a process by which a good faith effort can be made to better avoid adverse effects to deeply buried sites.

Before the guidelines can be fully implemented, it will be necessary for agencies, tribes, and the archaeological community to reach a consensus on the particular kinds of projects to which the guidelines should be applied. An attempt is made in this report to identify the major issues involved in such decisions. Carrying these considerations to the professional community was beyond the scope of the present project to address.

Given the added cost of subsurface testing, additional information on the location and spatial extent of high potential sedimentary environments in the state would be helpful in targeting subsurface testing efforts to place in the landscape, and within specific APEs, where buried deposits are most likely to occur. Geoarchaeological studies should be conducted within each archaeological region to better define the distribution and thickness of sedimentary environments. Coring, geomorphological mapping, and radiocarbon dating of relatively small areas in each archaeological region would provide a basis for recognizing similar stratigraphic contexts throughout the region (e.g., Hudak and Hajic 2001).

A considerable amount of geoarchaeological data is undoubtedly contained in the "gray literature" of cultural resources management. Reports that do not go into depth about the soils, sediments, and geomorphology of a site or project area will nonetheless often contain geoarchaeologically relevant information on the depth and age of buried components, topographic maps of landforms, and profile drawings. A project to review reports filed at ARC and build a geoarchaeological database would be worthwhile.

Applying guidelines for deep site testing in South Dakota will lead to considerable changes in how CRM archaeology is carried out in the state. Given the depth at which known, significant sites have been discovered, surface walk over and shallow testing alone are not sufficient to comprise a good faith effort to identify archaeological deposits in locations like river valleys, colluvial slopes, alluvial fans, sand dunes, and sand and loess sheets. In addition to added costs, implementing guidelines may also involve the acquisition of new skills and the integration of new concepts and approaches. This situation is similar in some respects to the rise of historic archaeology in the 1970s and 1980s. As archaeologists trained only in prehistoric archaeology began to face the need to record and evaluate historic sites as well, they developed knowledge of and appreciation for the more recent archaeological record. Similarly, in states that have adopted subsurface testing guidelines, archaeologists have become better informed about soils and landscapes, and attention to soils and sediments can lead to the discovery of significant buried sites that might otherwise have been missed.

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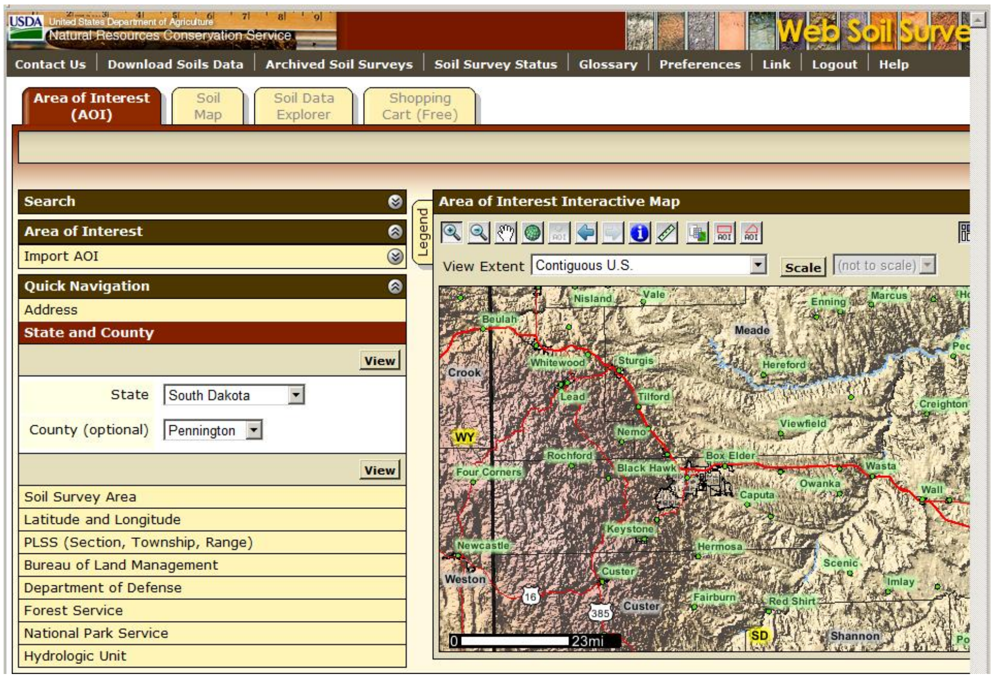
Appendix A: Using the Web Soil Survey

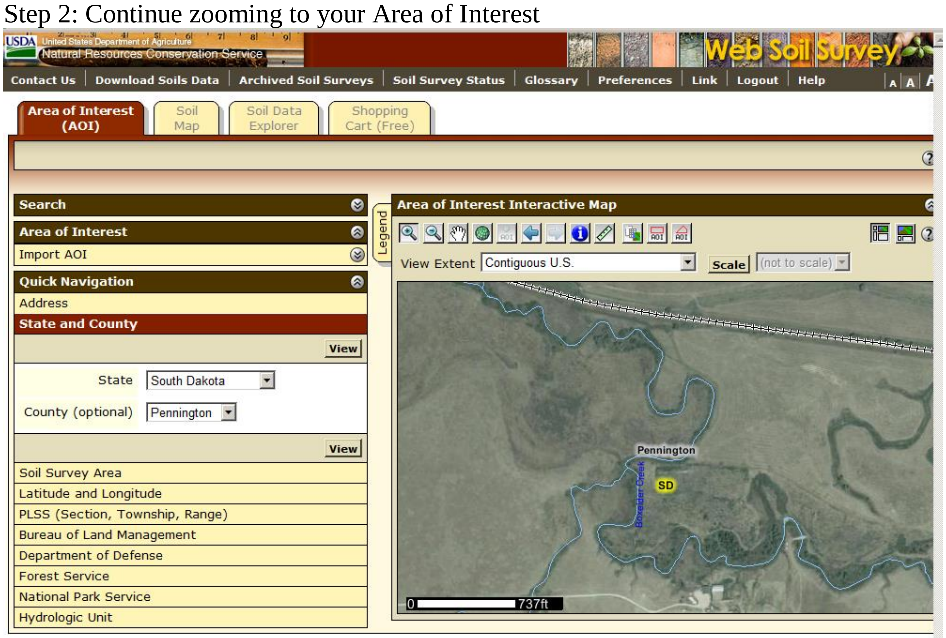
http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

Step 1: Identify Area of Interest (AOI)

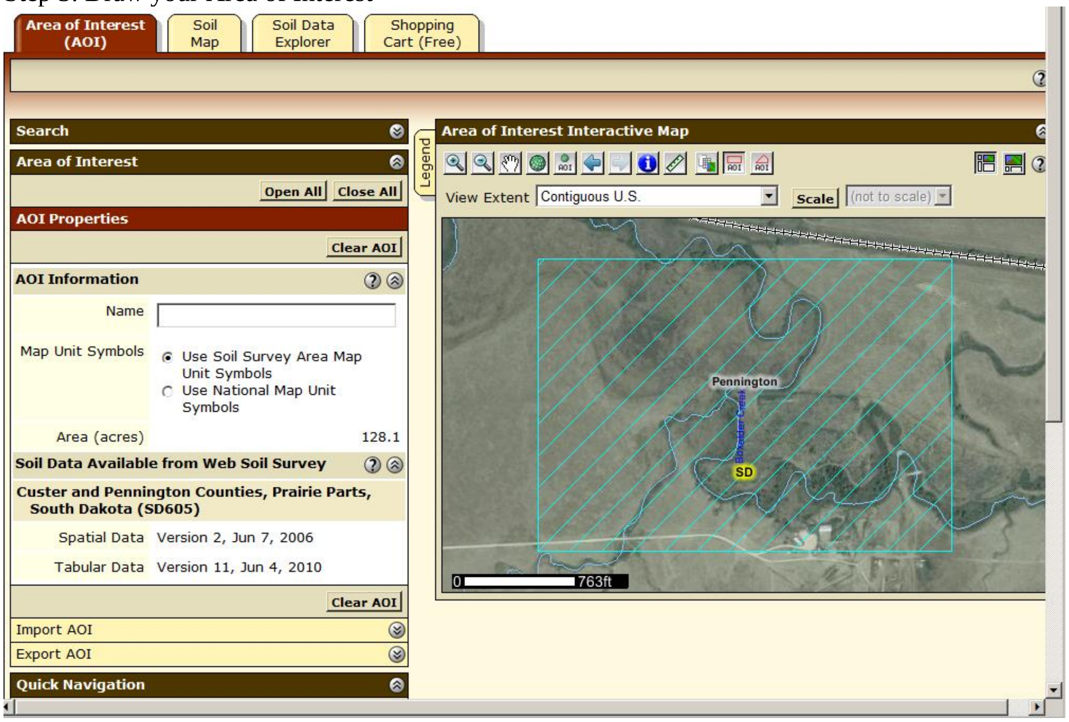


After selecting the State and County, Select View, and the map window will zoom to the county you've picked. Use the Magnifying glass tool at upper left of the map window to zoom in closer.

Step 2: Continue zooming to your Area of Interest

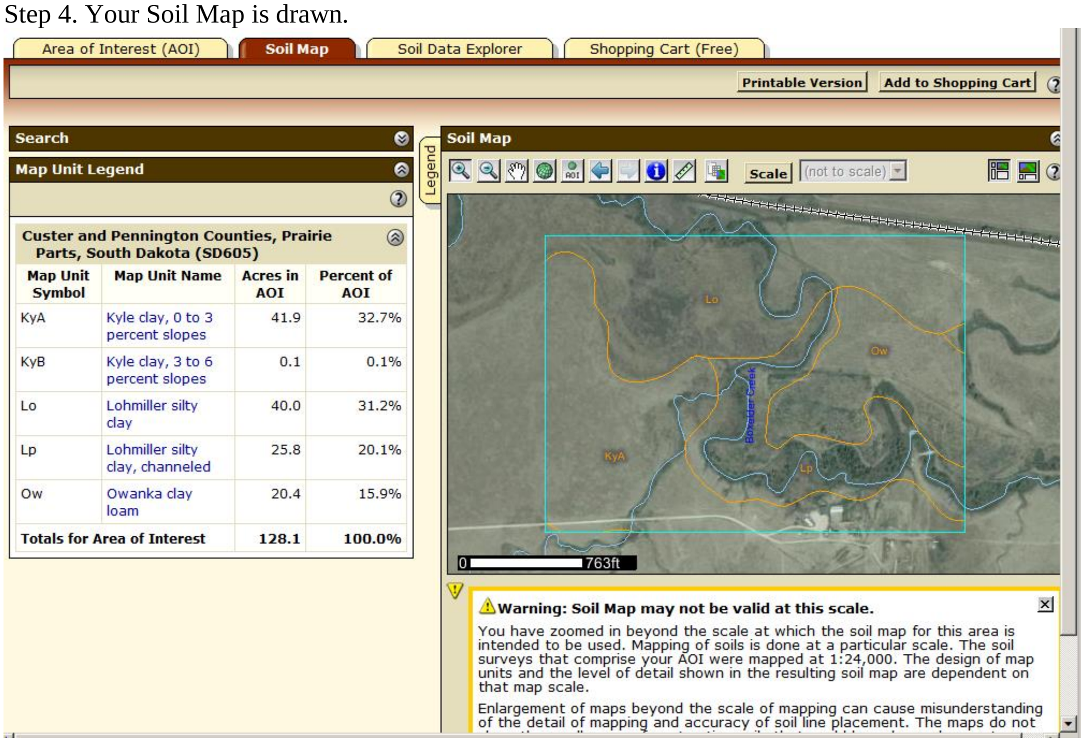


Step 3. Draw your Area of Interest



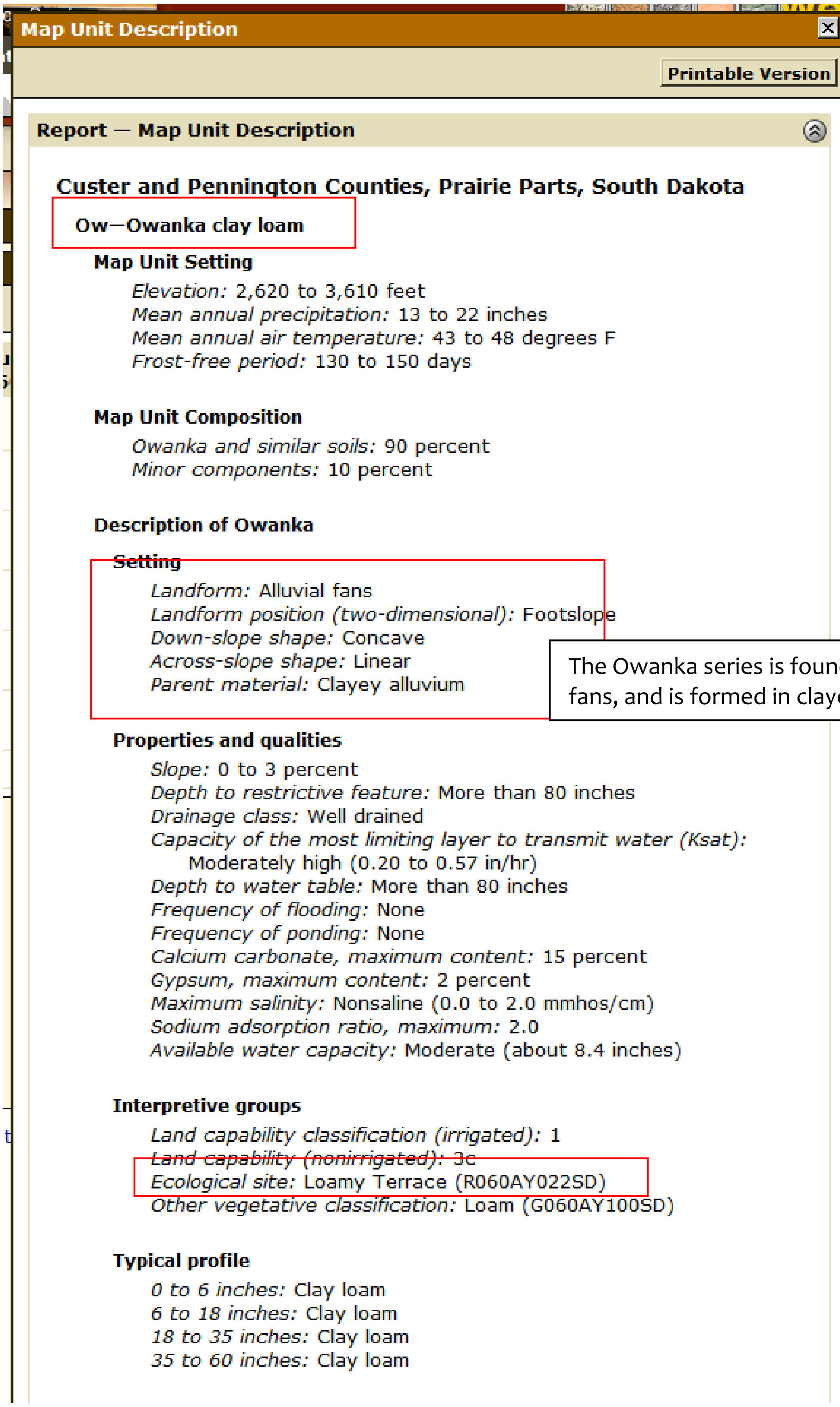
Use the AOI tools, one of which is depressed in the screen shot, above, drag a rectangle around the area you'd like to have a soils map of. Then click the Soil Map tab at top of screen.

Step 4. Your Soil Map is drawn.



The map unit symbols in the map pane are defined in the left hand pane. Click a blue hyperlink to display information about the soil.

Step 5. Examine the information about a map unit. Clicking Owanka clay loam in Step 4 opens this pop up window. For any soil you look up, information in Setting and Interpretive Groups identifies the landform and parent material of the soil, and gives you a heads up regarding buried site potential.



Map Unit Description

Printable Version

Report — Map Unit Description

Custer and Pennington Counties, Prairie Parts, South Dakota

Ow—Owanka clay loam

Map Unit Setting

Elevation: 2,620 to 3,610 feet
Mean annual precipitation: 13 to 22 inches
Mean annual air temperature: 43 to 48 degrees F
Frost-free period: 130 to 150 days

Map Unit Composition

Owanka and similar soils: 90 percent
Minor components: 10 percent

Description of Owanka

Setting

Landform: Alluvial fans
Landform position (two-dimensional): Footslope
Down-slope shape: Concave
Across-slope shape: Linear
Parent material: Clayey alluvium

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 15 percent
Gypsum, maximum content: 2 percent
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum: 2.0
Available water capacity: Moderate (about 8.4 inches)

Interpretive groups

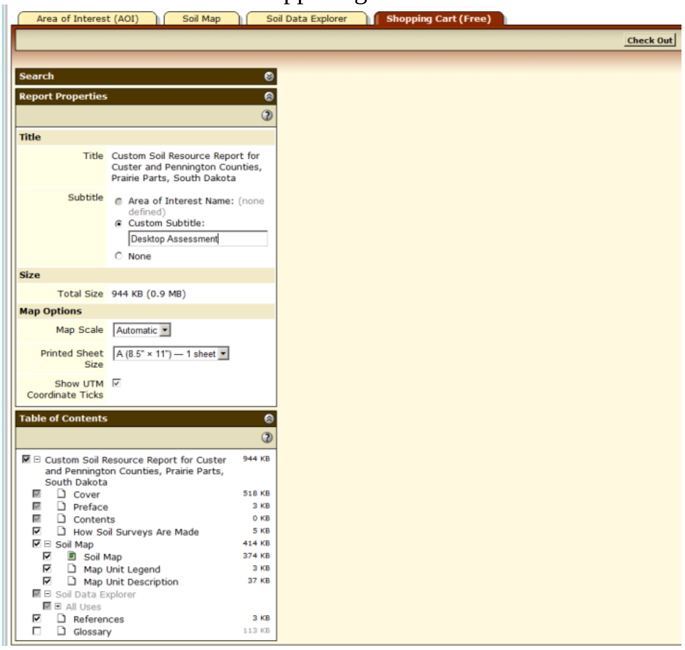
Land capability classification (irrigated): 1
Land capability (nonirrigated): 3c
Ecological site: Loamy Terrace (R060AY022SD)
Other vegetative classification: Loam (G060AY100SD)

Typical profile

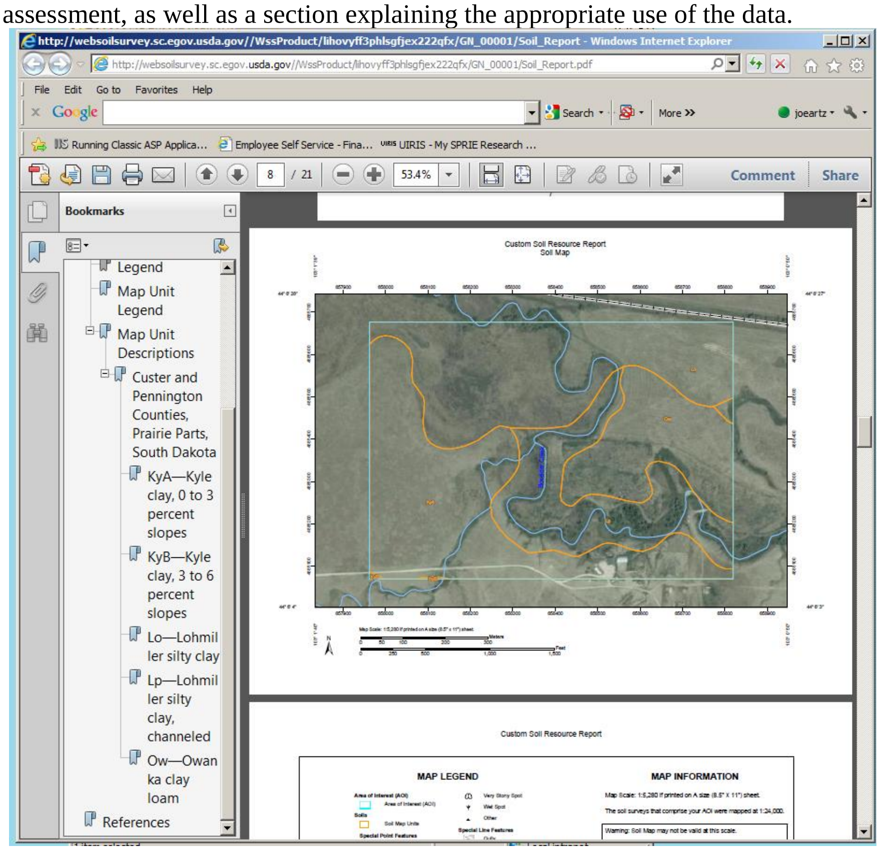
0 to 6 inches: Clay loam
6 to 18 inches: Clay loam
18 to 35 inches: Clay loam
35 to 60 inches: Clay loam

The Owanka series is found on alluvial fans, and is formed in clayey alluvium

Step 6: Downloading your results
Clicking on the Shopping Cart tab opens a window that allows you to save a report of your search. To proceed, click Checkout button at upper right.



Step 7. Print, save, or PDF the report. The report has the map and map unit descriptions needed for the desktop assessment, as well as a section explaining the appropriate use of the data.



Appendix B: Using GIS to Estimate Archaeological Site Density in South Dakota

An approximation of regional variability in site density can be derived from the data in the ARMS GIS datasets. Two steps were involved in the calculation. First, some sites and survey areas overlap one another. Simply summing the total area of survey and site polygons would therefore inflate the total area occupied by each. Geoprocessing tools were used to merge the areas of overlap into single, nonoverlapping polygons. Sites and survey polygons also overlap region boundaries, and therefore geoprocessing tools were used to split polygons at region boundaries. Sites and surveys are, of course, mapped and digitized at a much close scale than the statewide regions. The splits at region boundaries lend spurious accuracy, but were necessary for this first approximation analysis.

Total site and survey areas were calculated for each archaeological region (Table B1). The ARMS data indicate that 5.3% of the state's land area has been surveyed. Expressed as a percentage of the region's total area, survey density ranges from 0.5% in the Sand Hills region to 9% in the Bad-Cheyenne region to a somewhat improbable high of 54% in the Black Hills (Table B1, Figure B1, upper).

All sites not having been discovered, knowledge of site density is limited to areas where people have looked for, found, and recorded sites with ARC. Scrolling across South Dakota in a GIS, many ARMS sites are located outside ARMS surveys. These sites were not included in calculating site density because the extent of the area inspected for sites is not known. Only for surveyed areas can we estimate the ratio of site to nonsite area.

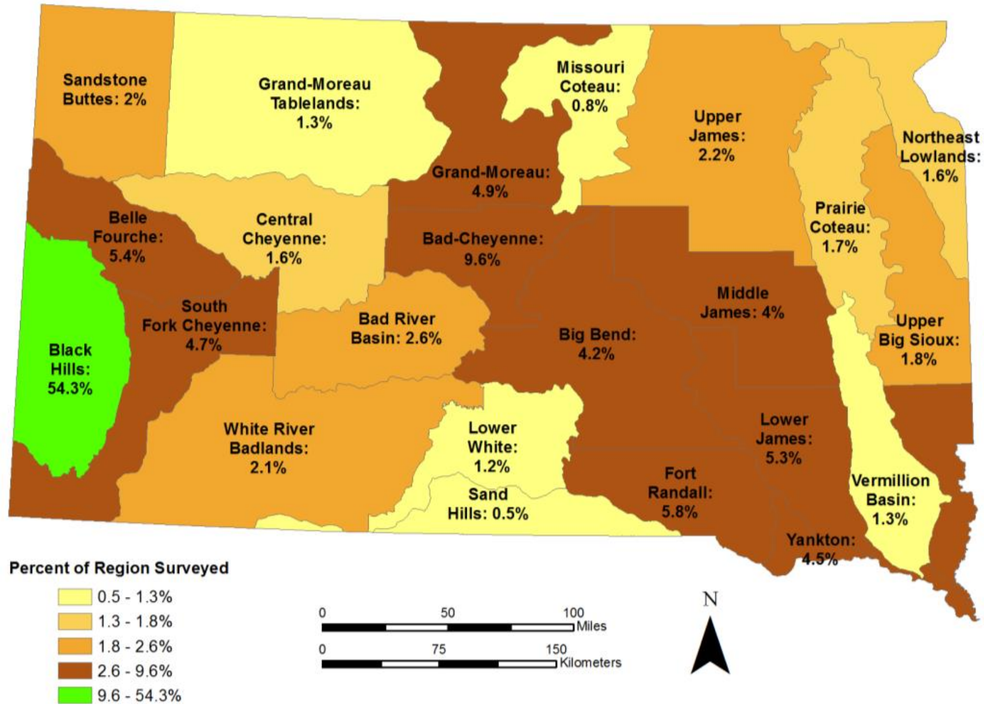
To calculate site density in the GIS, all sites with boundaries intersecting or contained within surveyed areas were selected. In an initial run of this process, 15,497 of 21,292 sites (73%) were selected. Visually scanning the ARMS GIS revealed that many of the sites not selected were in close proximity to a surveyed area. The proximity of sites to surveyed area may be coincidence, may have resulted from plotting/digitizing errors, or may be the result of surveyors occasionally wandering from the APE. All three factors probably pertain. Another pattern revealed by visual scanning were cases in which sites with areas in excess of 100 ha were intersected by only a few, small, digitized survey areas.

Given these vagaries, it was decided to err on the side of caution, and include only those areas of sites contained completely with a survey area. This was achieved by intersecting the sites and survey areas, removing all sites or portions of sites outside a survey area. The total area of sites within survey areas was then apportioned among archaeological regions.

As shown in Table B1, site density within survey areas ranges from 0.2% in the Sand Hills Region to 8.3% in the Bad-Cheyenne Region. Site density can also be expressed as the ratio of surveyed area to site area. These calculations (Table B1, Figure B1, lower) give a "fieldwork" perspective on site density. For example, for every hectare of archaeological site recorded in the Sand Hills, 502 ha had to be surveyed. On the other end of the spectrum, survey crews in the Bad-Cheyenne Region have been rewarded with a hectare of site for every 12 ha surveyed. Statewide, the ARMS data indicate that 1 ha of site has been found for every 40 ha surveyed.

Table B1. Site and Survey Density in South Dakota (source: ARMS).

Archaeological Region	Sites (ha)	Surveys (ha)	Region (ha)	% of Region Surveyed	% of Surveyed Area with Sites	Survey:Site Ratio
Bad River Basin	84	19,658	757,989	2.6%	0.4%	234
Bad-Cheyenne	4,616	55,637	579,186	9.6%	8.3%	12
Belle Fourche	530	35,210	647,623	5.4%	1.5%	66
Big Bend	1,921	54,995	1,303,106	4.2%	3.5%	29
Black Hills	12,291	485,602	894,569	54.3%	2.5%	40
Central Cheyenne	129	15,199	938,222	1.6%	0.8%	118
Fort Randall	472	37,552	643,547	5.8%	1.3%	80
Grand-Moreau	1,458	45,079	918,029	4.9%	3.2%	31
Grand-Moreau Tablelands	469	22,384	1,751,326	1.3%	2.1%	48
Lower Big Sioux	488	17,554	388,725	4.5%	2.8%	36
Lower James	233	38,830	737,242	5.3%	0.6%	167
Lower White	43	6,835	589,122	1.2%	0.6%	159
Middle James	470	37,914	939,260	4.0%	1.2%	81
Missouri Coteau	35	4,559	592,017	0.8%	0.8%	130
Northeast Lowlands	133	9,282	589,868	1.6%	1.4%	70
Prairie Coteau	161	12,373	744,313	1.7%	1.3%	77
Sand Hills	5	2,509	460,137	0.5%	0.2%	502
Sandstone Buttes	264	17,903	881,679	2.0%	1.5%	68
South Fork Cheyenne	543	41,984	894,251	4.7%	1.3%	77
Upper Big Sioux	189	12,753	699,026	1.8%	1.5%	67
Upper James	787	34,619	1,554,584	2.2%	2.3%	44
Vermillion Basin	96	7,333	580,937	1.3%	1.3%	76
White River Badlands	635	36,516	1,709,948	2.1%	1.7%	58
Yankton	290	8,143	182,433	4.5%	3.6%	28
Total	26,342	1,060,423	19,977,139	5.3%	2.5%	40



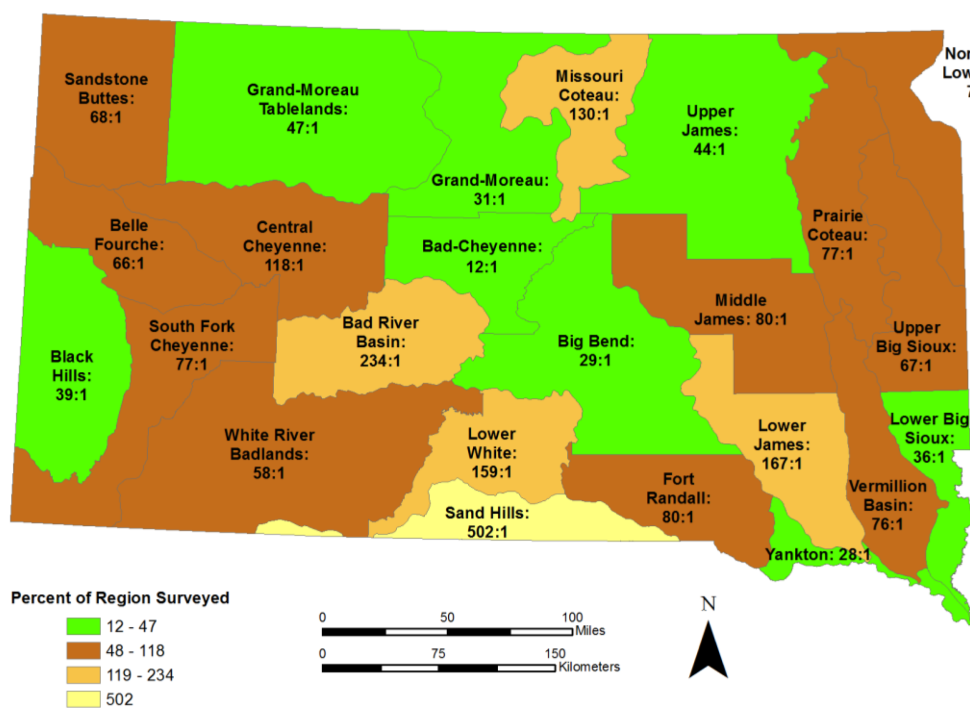


Figure B1. Survey and site density by archaeological region. Upper: percent area surveyed per region. Lower: site density as a ratio of total survey area to site area per region. Data from ARMS shapefiles. Site density is calculated using only archaeological site area that is contained within a survey area.