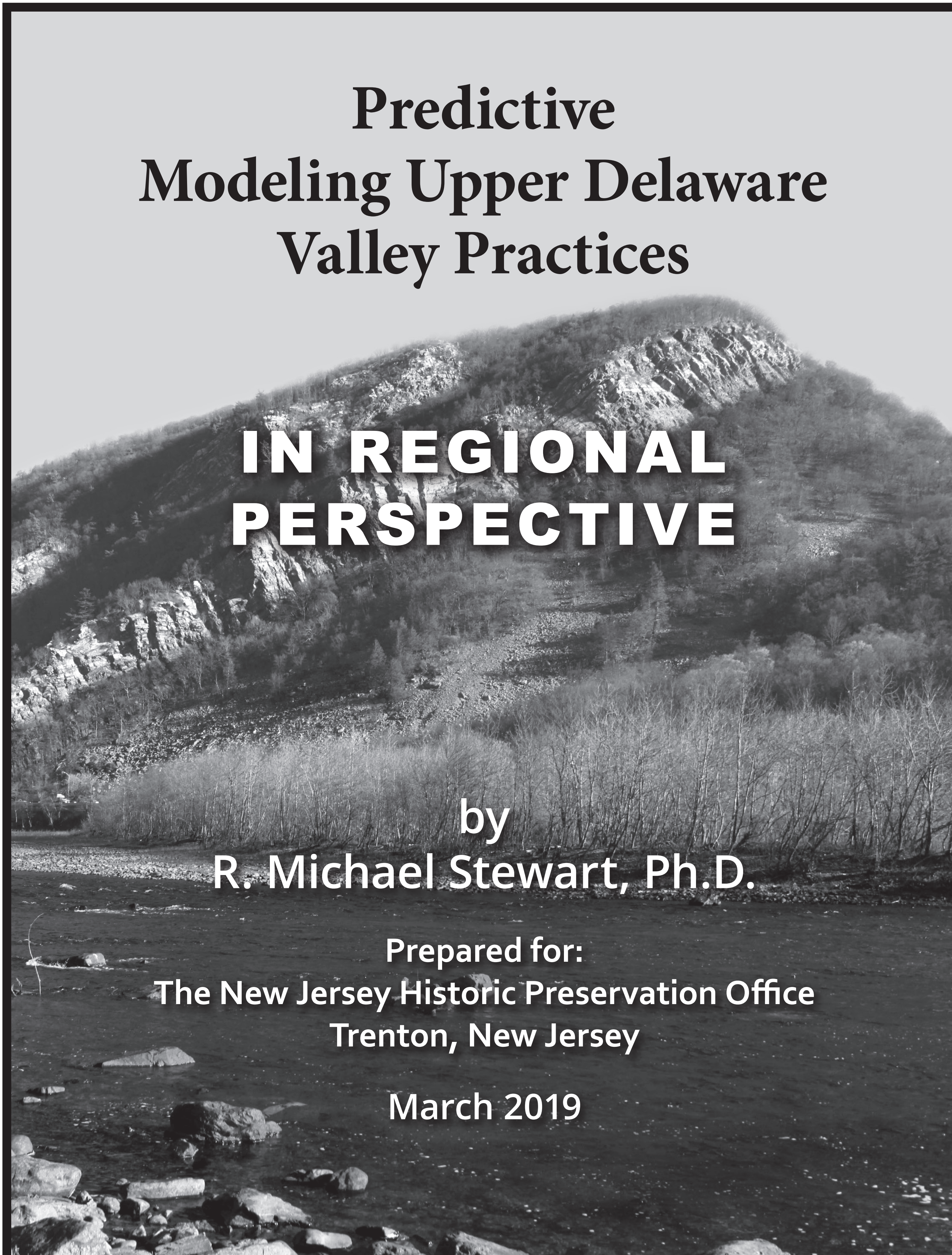

Predictive Modeling Upper Delaware Valley Practices

IN REGIONAL PERSPECTIVE

by
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Prepared for:
The New Jersey Historic Preservation Office
Trenton, New Jersey

March 2019

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I. INTRODUCTION

It is rare that archaeologists can examine 100% of anything in the field and this is especially true of reconnaissance surveys of extensive project or geographic areas. Sampling and the use of models that predict potential site locations or sensitive environmental zones typically are employed in these situations. In what follows I examine the use of predictive models for Native American sites in the Delaware Valley focusing on their use in the upper portions of the drainage basin. The effort is part of an alternative mitigation project supported by the New Jersey Historic Preservation Office. The overarching goal of the mitigation is to craft reports and essays that update and synthesize aspects of archaeological practice and the record of Pre-Contact and Contact Native American life in the Upper Delaware Valley, and understand them in the context of broader regional trends. The documents created provide contexts and highlight research issues to aid future academic and cultural resource investigations that involve this portion of the greater Delaware Valley.

The purpose of the modeling endeavor is to review the variety of approaches that have been used, highlight what appear to be best practices, and provide recommendations for how future modeling might be more effectively employed. The goal is not to establish a one-size-fits-all predictive model. Rather, it is to increase practitioners' awareness of the variables that can impact how native peoples distribute their activities across landscapes, how these variables might be integrated into models and related field methods, point out approaches that are not working or over-simplified, and recommend some field, analysis and reporting practices that should become standards in cultural resource management (CRM) investigations. A review of trends in the use of predictive models in the broader Middle Atlantic region provides contextual background for the examination of practices in the Delaware Valley and especially the Upper Delaware. As Harris (2013:1) notes "modeling is by its nature an exercise in trial and error, and by studying the history of modeling in the region, hopefully we may learn from the successes and avoid the pitfalls".

The types of models that have been employed are summarized and common themes to approaches identified, including the variables and associations that are considered to have the most predictive value. This is followed by a critique and discussion that considers how sites are defined, and existing state guidance on the use of models and related field methods. Biases inherent in the generation of models based on known site distributions and settings are addressed as is the quality of the environmental data employed, the impact of artifact collectors on the visibility of archaeological resources, and the nonrandom location of survey tracts defined by CRM projects.

What do we want to find in an archaeological survey? What are we supposed to find from a regulatory perspective? What types of archaeological resources are likely to be missed or under-represented? Are inductive models, those that are based on the settings of known sites, as effective as or more effective than explanatory models which take as their base current understandings of native lifeways through time? How sensitive are models to cultural and environmental changes over the past 13,000+ years? To what degree are factors other than those related to ecology and native economic practices considered in predictive models? How might insights from ethnohistory and ethnography be incorporated? Can settings where fine grained stratification and buried landscapes are likely to occur be incorporated effectively into site prediction models, or do they need to be modelled separately? These are questions raised in discussions below and reflected in recommendations made throughout the report.

For the purposes of this project the Upper Delaware Valley is defined by portions of the drainage basin that exist in the following states and counties (Figure 1): Warren and Sussex counties, New Jersey; Orange, Sullivan, Delaware, and Broome counties, New York; and Northampton, Monroe, Pike, and Wayne counties, Pennsylvania. The defined area is much larger than what has often been considered as the Upper Delaware by archaeologists in the past. For example, past definitions of the Upper Delaware have bounded it by the Delaware Water Gap on the south and Port Jervis to the north (cf. Custer 1996, Kinsey 1972; Kraft 2001). The Pennsylvania State Historic Preservation Office includes Northampton County in what it considers to be the Upper Delaware Valley, which extends the geographic boundary well south of the Water Gap. I have included Northampton County here to complement the downriver extent of Warren County in New Jersey. The degree to which all, or portions of the larger area used in this project correspond with Pre-Contact cultural or group territories remains an open question contingent on a variety of diachronic analyses.

Environmental scientists have used the designation, Upper Delaware Valley, in very different ways. From a hydrological perspective the Upper Delaware watershed refers to portions of the drainage basin from roughly the Port Jervis/Narrowsburg area of Pennsylvania/New York upstream through the East and West branches of the Delaware River in New York (e.g., Delaware River Basin Commission 2018; Goetz et al 2011:18; Pennsylvania Fish and Boat Commission 2011:37; USGS National Water Information System 2018). In 1978 Congress designated the Upper Delaware River as part of the National Wild and Scenic Rivers System. This encompasses portions of the river beginning at the confluence of the east and west branches of the river at Hancock, New York continuing downstream to the vicinity of Mill Rift, Pennsylvania, a few miles upstream from Matamoras/Port Jervis (Conference of Upper Delaware Townships and the National Park Service 1986). The area encompassed by the Delaware Water Gap National Recreation Area, long embedded in the consciousness of Middle Atlantic archaeologists as *the* Upper Delaware Valley, is considered as part of the Middle Delaware watershed (e.g., Delaware River Basin Commission 2018; Stinchcomb et al 2012). Defined as Water Management Area 1 in New Jersey, the Upper Delaware extends downriver to the mouth of the Musconetcong with the Delaware River in southwestern Warren County (Kelly and McGinnis 2001:Figure 1).

The project area encompasses portions of a number of physiographic provinces and related sections: the Reading Prong section of the New England Province, corresponding with the Highlands in New Jersey; the Ridge and Valley which includes the Great Valley and Appalachian Mountain (Blue Mountain, PA and Kittatinny Mountain, NJ) sections; and the Appalachian/Allegheny Plateau which includes the glaciated Low Plateau and Pocono Plateau sections in Pennsylvania, and the glaciated Low/Allegheny Plateau and Catskill sections in New York (Figure 2; Briggs 1999; New Jersey Geological Survey 2018; Perles et al 2007; Sevon 2000; Wolfe 1977:204-243).

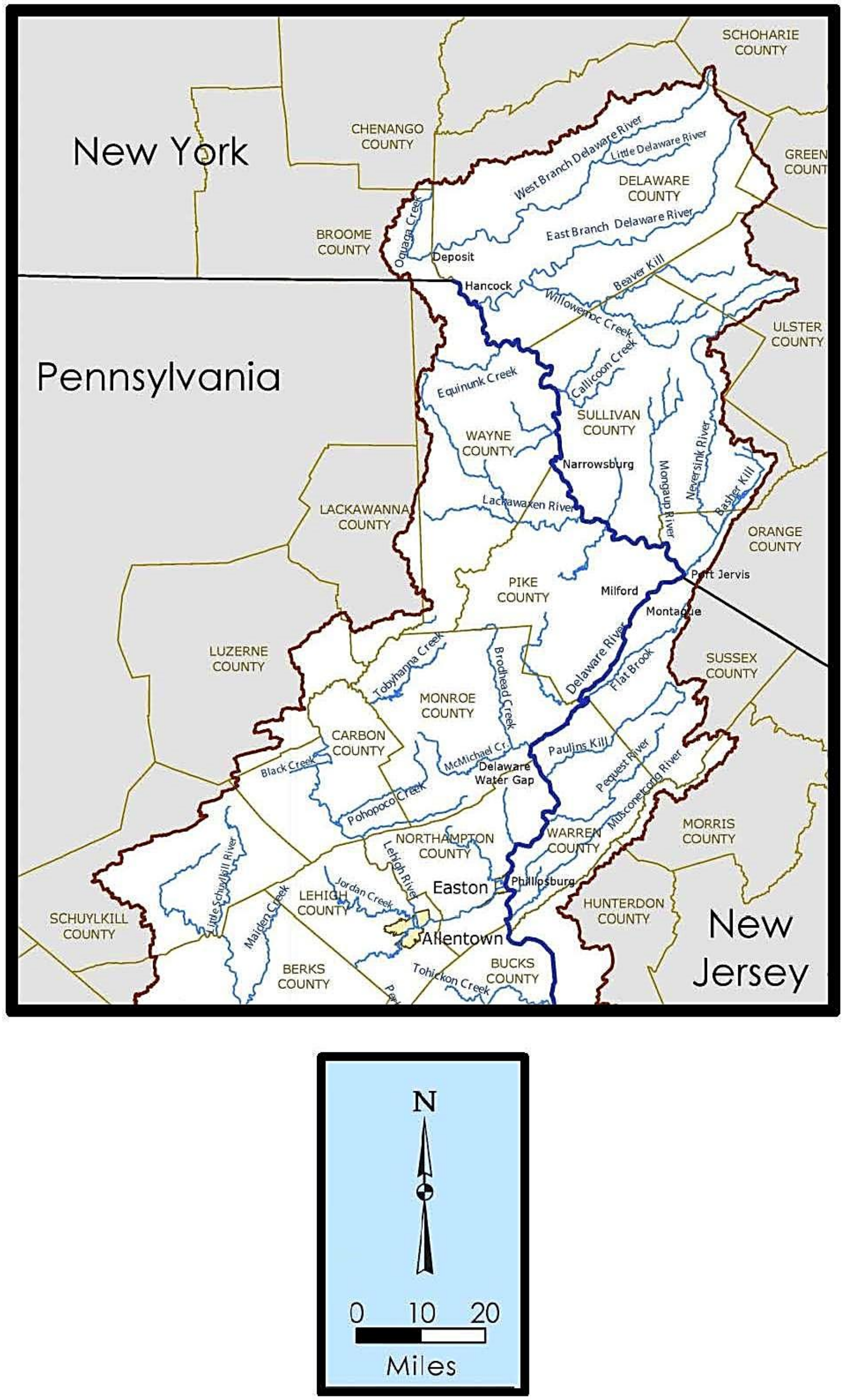

FIGURE 1. Upper Delaware Valley Project Area Showing Relevant Counties of New Jersey, Pennsylvania, and New York. Not labelled is Otsego County situated to the north of Delaware County, New York. The boundary of the Delaware River Basin is shown in red. Modified from a map available from the Delaware River Basin Commission at http://www.state.nj.us/drbc/library/documents/maps/counties.pdf.

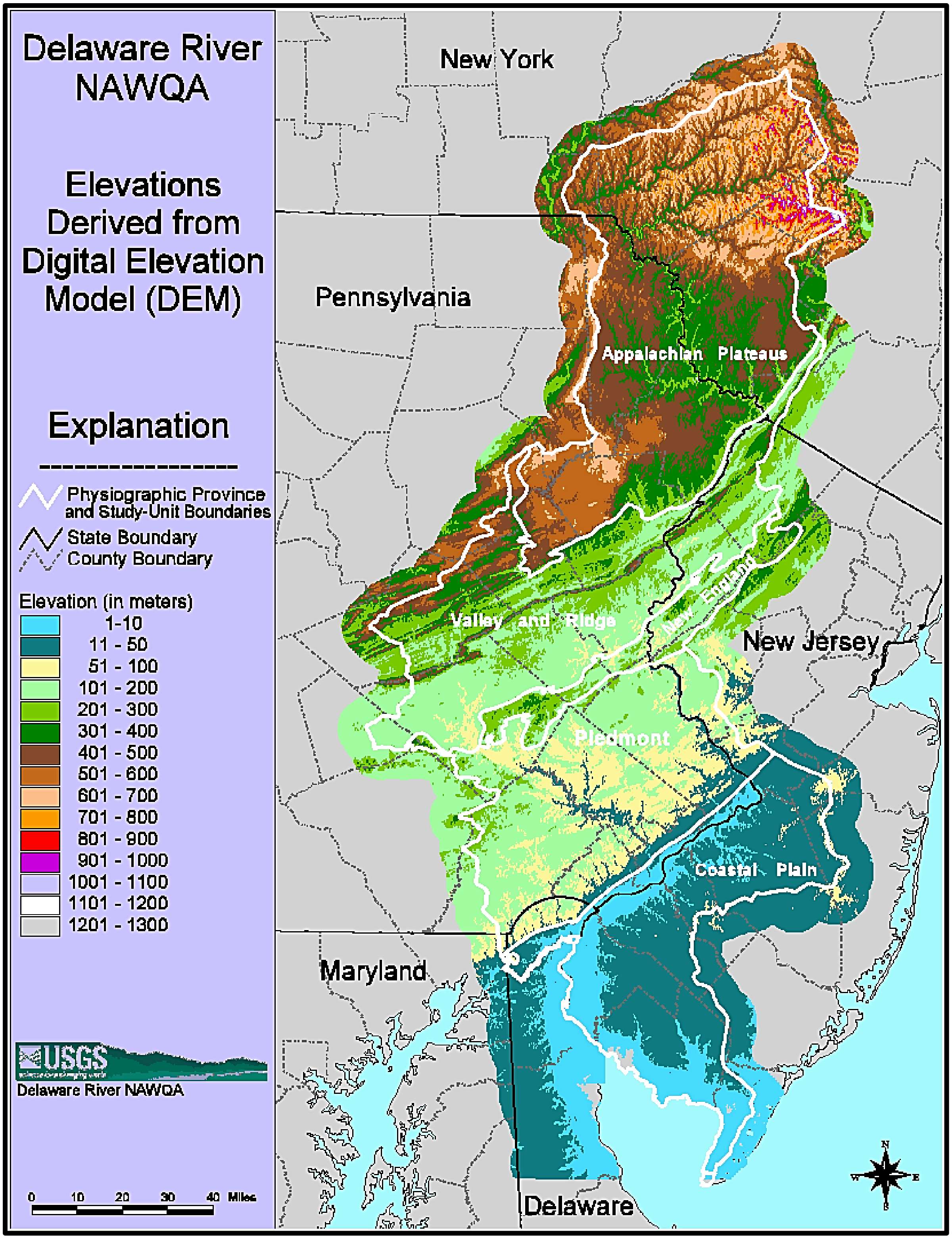

FIGURE 2. Physiography and Elevations in the Delaware River Basin. Source: USGS Delaware River Basin, National Water Quality Assessment Study, Study Unit Maps. **https://nj.usgs.gov/nawqa/delr/su_maps.html**

The New England Province/Reading Prong separates the Great Valley from the Piedmont. The Reading Prong is characterized by discontinuous circular to linear rounded hills and ridges with rugged terrain of moderate relief and dendritic drainage patterns. For archaeologists it is most famously known as the area in which the Hardyston Formation and associated jasper deposits and related Native American quarries occur (e.g., Anthony and Roberts 1988; Boulanger and Stewart 2018; Stewart 2016). Sources of chert also are known (e.g., Bayley 1941:86; Tomaso and Eshelman 2014, 2015).

The Great Valley section is a broad valley with low to moderate relief and karstic terrain in portions relevant to the project area. The Appalachian Mountain section consists of long narrow ridges and broad to narrow valleys. It is an area of moderate to high relief with trellis, angulate and some karstic drainage patterns. The Blue Mountain to Kittatinny Mountain section (Pennsylvania and New Jersey) is a linear ridge to the south with shallow valleys to the north and east exhibiting moderate to high relief and a trellis drainage pattern. The Ridge and Valley Province is an area rich in potential lithic sources for use in a chipped stone technology. The carbonate geology of Warren and Sussex counties, New Jersey and Northampton and Monroe counties in Pennsylvania possess sources of cherts for potential use as toolstone (e.g., Drake 1965; LaPorta 1994a, b, 2009; Pevarnik and Blondino 2010; Stinchcomb et al 2009; Willard 1938:13-14, 16, 30). Potential sources of steatite/talc also are known (Bachor 2017:Table 2.3; Bayley 1941:12, 94; Geyer et al 1976:193-198; Gordon 1922:152; Greene 1995:100-102; Miller 1939:6, 42; Schrabisch 1917:47) in addition to a variety of lithic materials suitable for the fashioning of ground stone tools and implements.

Formerly glaciated areas of the Ridge and Valley Province support lakes, ponds, swamps and bogs, and wetlands formed in depressions created by glacial scouring (e.g., Sevon and Braun 2000; Wolfe 1977:217-224). Notable among these are the Great Meadow and "black dirt" areas of New Jersey. The Great Meadows wetland formed following the draining of glacial lakes in the Pequest and other watersheds (Wolfe 1977:218, 234). The black dirt area is the remnant of extensive wetlands and peat deposits that developed in the former basins of glacial lakes in the Wallkill River Valley of portions of Sussex County, New Jersey and Orange County, New York (Connally and Sirkin 1970; Freedman 2009; Funk 1992:28; Gramly et al 2017; Pretola and Freedman 2009:128-171; Witte 2011). A variety of Pleistocene megafauna have been documented in the area (e.g., Pretola and Freedman 2009:Table 2). Vesper and Gramly (2016) report 66 finds of proboscideans from Orange County, New York.

The glaciated Low Plateau is characterized by rounded hills and valleys with low to moderate relief and dendritic drainage patterns. Valleys are relatively straight separated by irregular intervening ridges with moderate and variable relief and numerous small water bodies. The glaciated Pocono Plateau section is a broad undulating upland with dissected margins and exhibiting low to moderate relief. The drainage is characterized as deranged with swamps and beat bogs in depressions created by glacial scouring. The Appalachian/Allegheny Plateau in the New York portion of the Delaware watershed is largely made up of the Catskill section.

Devonian-aged bedrock occurs in Pennsylvania and New York plateau areas of the project area. In the Ridge and Valley Province of Pennsylvania and New Jersey Devonian formations include sources of chert (e.g., Harper 1999; LaPorta 2009). However, the Devonian

Catskill Formation and its members mapped for the plateau areas of Pennsylvania and New York are comprised of mudstone, claystones, siltstones, sandstones and conglomerates with no knappable toolstone (Berg and Dodge 1981:269, 324, 408, 418, 538; Briggs 1999:Table 30-2; Harper 1999:Table 7-1; Perazio and Presler 2005:3; Ver Straeten 2013). In New York Helderberg cherts outcrop west of the Hudson River along the Allegheny Plateau between the Normanskill and Onondaga formations (Cassedy 1992). It is possible that useful toolstone is represented to some degree in glacially transported gravels or tills in the plateau areas.

The variability in topography, elevations, geology, and edaphic factors throughout the project area influences the nature of forest and plant communities, and ultimately the faunal species that occur now, and during the environmental changes of the past. Today notable differences can be noted between the Ridge and Valley and glaciated Plateau provinces with the area from the Water Gap to the New York line transitional between the vegetation to the south and to the north (cf., Davis and Edinger et al 1991; Davis, Edinger and Smith et al 1991; Kudrle 2011:Table 2, Figures 8, 25; Rhoads and Klein 1993; Robichaud and Buell 1973:262).

These brief summaries of aspects of the environment are meant to convey some sense of the variability that is encountered across space. In that predictive models of archaeological site locations are intrinsically tied to understandings of the environment, we should not expect a single model to be broadly applicable. This issue is explored in greater detail throughout the discussions below.

Models employ observable and measurable aspects of the environment, in conjunction with varying assumptions about human ecology and behavior (economic, social, religious, etc.), to predict where on a given landscape material evidence of activity might be found. That early regional attempts at modeling highlight connections between the environment, human ecology, and economic activities is not unexpected given the variables and associations employed in their construction (e.g., Beckerman 1978). Thinking of culture and environment as coupled systems an observation by Salmon (1978:179) is worth repeating.

> Modeling always ignores some, often fundamental, aspects of a system in order to focus on others. No one model should or does model every feature of a system. Whether a model is good or bad depends partly on our purposes in constructing the model.

An implication of this position is that even the best economically-oriented models need not account for sites whose locations are due to other factors. Examples of such factors include the season of occupation, the location of previously occupied camps and settlements, population size and density, travel routes, culturally significant landscapes, and political or territorial relationships.

Modeling by archaeologists is of two types, inductive, and explanatory or deductive. Inductive models are those that are based on the analysis of known site locations and their environmental associations and are often atemporal in nature. The inductive approach accounts for the majority of models used in the Middle Atlantic Region, now and in the past. Explanatory predictive models, or models that are deductively derived, attempt to predict how particular patterns of human land-use and assumptions about human behavior and decision making will be reflected in the archaeological record (cf. Bettinger 1980; Church et al 2000:135 citing Sebastian and Judge 1988:4). Such models predict human responses and their archaeological fingerprints to specific environmental/socio-cultural/demographic contexts based on the postulated causal relationships of these variables (e.g., Bettinger 1980:203). Explanatory models are time sensitive. There is, of course, an inductive aspect to explanatory models in that the analysis of known archaeological deposits are the basis for understanding the environments and socio-cultural systems of the past and deriving patterns in human behavior through time. Explanatory models are represented in the literature of the Middle Atlantic. Both inductive and explanatory models may focus on the archaeological sensitivity of very specific locations or small landscapes, or on broader landscapes or environmental zones.

Data marshalled for this report were derived from a review of all cultural resource management (CRM) reports for Warren and Sussex counties on file at the New Jersey Historic Preservation Office as of 2016. Select Phase I and all Phase II and Phase III CRM reports for New York and Pennsylvania portions of the Upper Delaware Valley also were reviewed, including significant Phase II and Phase III reports for Pennsylvania and New York areas adjacent to the Upper Delaware Valley. Relevant published literature also was consulted for the project area in addition to select CRM reports and the published literature for the broader Middle Atlantic Region.

II. BACKGROUND: REGIONAL

A. Early Trends in the Middle Atlantic Region

In the Middle Atlantic region heightened concern with sampling strategies and the development of predictive models took off during the 1970s paralleling national and international concerns with these issues (e.g., Hodder and Orton 1976; Jochim 1976; Mueller 1974, 1975; Plog 1978; Wood 1978), their utility in cultural resource management investigations, and the proliferation of settlement pattern studies to which models are often linked (see Wall 2018 for review). Examples of early work in the region include Beckerman (1978), Cavallo and Mounier (1980), Custer (1979), Custer and Wallace (1982), Dekin et al (1983), Eveleigh (1984a, b), Eveleigh et al (1983), Gardner (1978, 1983, 1987), Gardner and Custer (1978), Grossman and Cavallo (1982), Hasenstab (1983, 1984, 1991), Hatch et al (1982), Hay and Hatch (1980), Hughes and Weissman (1982), Kavanagh (1980, 1982), Lantz et al (1982), LeeDecker (1984), Peck (1979), Stewart (1980), Tolley (1983),Wall (1981), and Wilke and Thompson (1977). Details regarding the environmental associations of sites are more incidental to other settlement patterns studies (e.g., Ritchie and Funk 1973).

Table 1 lists the variety of variables employed in early modeling efforts from the Middle Atlantic region, including examples from the greater Delaware Valley. Projects specifically related to the Upper Delaware are reviewed in a later section of this report. Listed variables are interrelated to various degrees in the models referenced. The dynamic relationships that a given model proposes are impossible to capture in a table. A number reflect the uniqueness of a given environmental zone and are time transgressive, reflecting current understandings of environmental change, settlement and subsistence patterns, and suppositions regarding population size and density.

Variable states and relationships are not always quantified in early models making the ranking of site potential for a particular landscape a fairly subjective exercise. It is a tacit assumption that a variety of factors impact the data used to fashion models including: the activities of artifact collectors, the accuracy of data dealing with known sites (including mapped locations), site size, site function, season of site use, the degree to which documented sites represent the topographic and environmental settings of an area, geomorphology, survey field methods and conditions, and sampling strategies.

It is clear that some variables and associations are more relevant to specific physiographic provinces or micro-geographic areas than others, and that the utility of some variables changes through time and with site function. For example, Wall's (1981) analysis of site locations in the Allegheny Plateau of western Maryland details the shifting importance of variables depending on local environmental zones such as floodplains, foothills, and uplands (also see Hughes and Weissman 1982:15-19). Early Archaic hunting stations in the Blue Ridge province of Maryland occur at greater distances from surface water than other types of sites (Stewart 1983:52). The intensity of the use of mountainous zones in general reflects environmental change and associated resource potentials, the nature of adaptive systems and the role of transhumance within them (e.g., Gardner 1983). In the Ridge and Valley of Maryland a

TABLE 1
Variables Highlighted in a Sample Of Early Settlement and Site Location Models for the Middle Atlantic Region

VARIABLES*	REFERENCES
stream confluences	Custer (1983a, 1986a); Custer et al (1986); Custer and Wallace (1982); Gardner (1978, 1983, 1987); Gardner and Boyer (1978); Gardner and Custer (1978); Hasenstab (1983, 1984, 1991); Hay and Hatch (1980); Hughes and Weissman (1982); Lantz et al (1982); Stewart (1980, 1983); Tolley (1983); Wall (1981)
springs/spring heads/drainage heads	Custer and Wallace (1982); Gardner (1978, 1983, 1987); Gardner and Boyer (1978);Lantz et al (1982); Snethkamp (1981); Stewart (1980, 1983); Tolley (1983); Wall (1981)
floodplain swamp/wetland/floodchute	Cavallo and Mounier (1980); Custer and Wallace (1982); Eveleigh (1984); Eveleigh et al (1983); Gardner (1978, 1987); Wall (1981)
sinkholes	Custer (1983a, 1986a); Custer and Wallace (1982); Gardner and Custer (1978); Wells (1981)
bogs, marshes, swamps, ponds, wetlands in general, including periglacial features	Bonfiglio and Cresson (1978, 1982); Cresson (1978); Custer (1983a, 1986a); Cavallo and Mounier (1980); Custer et al (1986); Custer and Wallace (1982); Eveleigh (1984); Eveleigh et al (1983); Gardner (1983); Gardner and Boyer (1978); Gardner and Custer (1978); Hasenstab (1983, 1984, 1991); Lantz et al (1982); Stewart (1980, 1983); Tolley (1983); Wall (1981); Wells (1981)
stream order	Custer (1983a, 1986); Custer et al (1986); Eveleigh (1984); Eveleigh et al (1983); Gardner (1978, 1987); Gardner and Custer (1978); Hay and Hatch (1980); Stewart (1980); Wells (1981)
distance from surface water	Cavallo and Mounier (1980); Custer et al (1986); Eveleigh (1984); Eveleigh et al (1983); Hasenstab (1983, 1984, 1991); Hughes and Weissman (1982); Kavanagh (1980, 1982, 1983); Peck 1979; Gardner (1978, 1987); Snethkamp (1981); Stewart (1980); Wells (1981)
distance from high order streams	Custer (1983a, 1986); Gardner (1978, 1987); Hasenstab (1983, 1984, 1991); Stewart (1980); Wells (1981)
height above surface water	Hughes and Weissman (1982); Kavanagh (1980, 1982, 1983); Peck (1979); Snethkamp (1981)
soil drainage/permeability	Custer et al (1986); Eveleigh (1984); Eveleigh et al (1983); Hasenstab (1983, 1984, 1991); Hughes and Weissman (1982); Kavanagh (1980, 1982, 1983); Peck (1979); Wells (1981)
soil associations	Gardner and Custer (1978)
soil productivity	Hay and Hatch (1980)
aspect/maximum sunlight exposure	Custer (1983a, 1986a); Gardner (1978, 1987); Snethkamp (1981)
slope/gradient	Peck (1979); Wells (1981)
lithic resources	Custer (1983a, 1986a); Gardner (1978, 1987); Wall (1981); Hay and Hatch (1980)
zones of maximum habitat overlap	Custer (1983a, 1986); Gardner (1978, 1987); Gardner and Custer (1978); Hay and Hatch (1980); Stewart (1980)
alluvial fans	Gardner (1978, 1987); Gardner and Custer (1978); Wall (1981)
high order stream levee	Gardner (1978, 1987); Gardner and Custer (1978); Wells (1981)
floodplain/terrace margins	Custer (1983a, 1986a); Cavallo and Mounier (1980); Gardner (1978, 1987); Snethkamp (1981); Wall (1981)
hilltops	Kavanagh (1980, 1982, 1983); Wall (1981)
geomorphic setting	Gardner and Custer (1978)
upland saddles, ridges, flats at the heads of hollows	Gardner (1983); Tolley 1983

*Well drained ground with minimal slope in proximity to many of the variables listed is frequently assumed.

wide variety of stream orders and topographic settings is associated with Early Archaic sites, a trend that was initially envisioned to begin during Middle Archaic times (Stewart 1980). Cobble deposits that include useful lithic materials do not seem to influence site locations in this area (Stewart 1980) in contrast to patterns in other physiographic zones (e.g., Gardner 1978, 1987;

Wall 1981). The critical importance of lithic sources in Paleoindian settlement patterns in the region has long been recognized (e.g., Custer et al 1983; Gardner 1974, 1977, 1989).

A number of early projects in the region outside of the Delaware Valley are notable in representing quantitative approaches (Gardner and Custer 1978; Custer 1979; Kavanagh 1980, 1982, 1983; Hughes and Weissman 1982). Analyzing the results of informant interviews and a previous survey of environmental transects oriented across the major drainages of a portion of the Shenandoah Valley in Augusta County, Virginia, Gardner and Custer (1978) distinguished culturally significant zones used to partition an enlarged survey. Chi-square and difference-of-proportion tests were used to examine whether a dependent relationship exists between the temporal-cultural affiliation of sites and the specific features of their environmental settings. Environmental variables included landform type (a variety of floodplain, terrace, and hilltop settings), soils associations, and surface water associations (stream rank, confluences). Proximity to lithic resources was not considered because no specific project area possessed a favorable position in relation to potential sources. Dependent relations were demonstrated for cultural temporal affiliation, individual environmental variables, and combinations of variables. The environmental partitions were then used to craft a proportionately stratified sampling scheme to guide archaeological survey (Gardner and Custer 1978:30-40,Tables 4-16). Following the survey the results were used to project the density of sites by environmental strata for the entire project area. The highest probability environmental strata included specific combinations of soil associations, stream rank and landform (Gardner and Custer 1978:Table 22). Custer's (1979) subsequent dissertation expands upon this work, but with an emphasis on demonstrating the most effective sampling strategies for use in archaeological survey.

Working in the Monocacy River basin (the Piedmont of Maryland) Kavanagh (1980, 1982, 1983) combined the results of three different approaches to site survey to assess the predictive value of a variety of environmental variables. Site data was derived and analyzed from three different approaches: the re-examination of previously recorded sites; a survey of arbitrarily selected transects; and a survey of randomly selected quadrats. A variety of environmental variables were examined including distance to and height above water, stream order, landform types, different degrees of slope, and soil drainage. From an atemporal perspective, survey areas that included a combination of short distance from water (200 meters or less), 15 meters or less above water level, slopes of 0-15%, and well drained to excessively drained soils consistently accounted for the majority of sites (77%) irrespective of approach (Kavangh1982:35, 1983:42).

She significantly concludes that "the power of these 'predictors' will depend on the proportion of the of the study area possessing the predictive characteristics alone, and in combination" (Kavanagh 1982:35). The predictor variables could be noted for 36% of landforms in the Monocacy Valley study area with the implication being that as this percentage increases predictive power decreases. This mirrors to a degree the conclusions and methodologies promoted in later publications by Kvamme (1985, 1989) which are frequently cited by those constructing and revising predictive models. The value of the other variables used in the Monocacy study changed when a cultural historical perspective was taken. For example, stream order was not significant from an atemporal perspective but was important when considering Paleoindian and Early Archaic sites which exhibited a riverine orientation.

Hughes and Weissman (1982) evaluated the previous work of Kavanagh (1980, 1982), Peck (1979), Stewart (1980), and Wall (1981) and the utility of the variables embedded in their models for the Allegheny Plateau, Ridge and Valley, and Piedmont zones of Maryland. Focusing on those most common and said to possess the highest predictive potential they isolated the following for testing with a sample of 539 known sites: proximity to nearest watercourse; height above watercourse, distance to nearest watercourse confluence; soil drainage characteristics; degree of land surface slope; landform; and site aspect. Frequency tabulations, principal components analysis, principal factors analysis, and multiple regression analysis were used to examine the relationship of the variables and their ability to account for the variation in site locations (Hughes and Weissman 1982:85-94, Appendix 1). Distances to water of 200 meters (656 feet) or less account for the greatest percentage (70% and greater) of sites in all three physiographic provinces (Hughes and Weissman 1982:Table VI.I). Equally significant is height above watercourses of 18 meters (59 feet) or less (75% and greater of sites). Distances to stream confluences of 500 meters (1640 feet) or less account for a slim majority of sites (51-65%). Well-drained to excessively drained soils are associated with roughly 81-87% of sites in the Piedmont and Ridge and Valley but account for less than 50% of sites on the Allegheny Plateau.

Beckerman (1978) modelled the intensity of use of a given area (sampling unit) based upon measures of environmental productivity, rather than specific site locations. This parallels to a degree the notion of site-less survey (e.g., Dunnell and Dancey 1983; Ebert 1992) and landscape approaches in archaeology (e.g., David and Thomas 2008), as well as the synoptic approach to modeling represented by the work of Wells (1981), Eveleigh et al (1983), Eveleigh (1984a, b) and Custer et al (1986) in coastal Delaware (see below).

A similar type of approach was employed by Hay and Hatch (1980) in a survey of the Bald Eagle Creek watershed in Pennsylvania wherein environmental factors related to the economic desirability of a survey square (one mile on a side) were ranked in order to predict the distribution and density of archaeological sites rather than their exact locations on a landscape. Variable states of environmental features (access to water, topography, availability of lithic resources, and access to two or more ecozones) in each square were assigned points with the total points for a square an indication of its economic/resource desirability. The modeled desirability of areas was then compared with the known distribution of sites. A distinct increase in site density with increased habitat desirability was demonstrated. Late Woodland sites also tended to be located on landscapes with high yield soils, or those highly rated for corn production. This contrasted with trends in the nature of soils associated with sites of earlier periods (Hay and Hatch 1980:88).

An implicitly economic behavioral model was tested by Curtin (1981) in an upland area in central New York. The initial development of the model was led by Albert Dekin, Jr. and archaeologists at SUNY Binghamton. Dekin and colleagues would employ a similar model in a survey of portions of the Upper Delaware Valley (Dekin et al 1983). The core of the model is the assumption that sites are more likely to occur in areas that are more varied environmentally; the greater the degree of environmental heterogeneity of an area, the greater the probability of site occurrence. The range and size of topographic and geomorphic features, types of surface water, stream order, stream confluences, wetland habitats, and slope were used to derive a score of the environmental diversity of individual hexagonal grid units overlaid on the area to be surveyed.

Hexagons measuring 1 kilometer from side-to-side were chosen because they pack evenly and measure space more efficiently than squares or rectangles. Circles provide a more precise measure of variability around the point, but circles lack the requirement of even packing (Curtin 1981:89). A random sample of hexagonal units was drawn for site survey.

Statistical analysis of survey results revealed the utility of the model. The model predicts the probability of encountering one or more sites within a hexagonal area, not the actual location of a site. An examination of the frequency with which individual variables were associated with site occurrences indicated that:

> …there is a nested hierarchical relationship between locational factors, with larger scale environmental heterogeneity being initially important, and more specific, smaller scale geomorphological variables becoming important next. Since geomorphological variables are distributed in high frequency in many low sensitivity hexagons, where sites tend not to occur, it is difficult to imagine how a specific geomorphological variable could predict site locations effectively by itself (Curtin 1981:96).

This conclusion emphasizes that the predictive value of individual variables is impacted or varies by their representation in the broader environment; the greater their representation in the background environment the less significant their predictive value (cf. Kavanagh 1982:35; Kvamme 1985, 1989). The range of variables employed in the model can be modified depending on the nature of the area being surveyed, as can the size of the hexagonal units used to grid and characterize survey area environments (Curtin 1981:97).

The work of Stevenson (1982) in upland areas of the Allegheny Front in Pennsylvania represents another type of behavioral or deductive/explanatory model. The spatial distribution and seasonal productivity of mast producing tree species and the seasonal behavior of deer populations were modeled for different types of upland hollows. In conjunction with assumptions about hunter gatherer behavior drawn from ethnographic and archaeological studies the location of camps and foray-related sites was proposed following the work of Jochim (1976). The model was found to be appropriate on a general level (Stevenson (1982:15).

B. Early Trends in the Delaware Valley and New Jersey

Perhaps unique in regional archaeology is the early assessment of factors responsible for the location of Indian camps or villages in New Jersey by Skinner in 1913, working in conjunction with Max Schrabisch. "These are generally situated near fresh water, often on a sandy, well drained bluff or knoll, on the north side of a stream or lake, where the southern exposure gives added warmth in the coldest weather" (Skinner 1913:10). Rockshelters, caves, and the concave sides of huge detached masses of bedrock are used when near fresh water and where there is a southern exposure (Skinner 1913:13). Schrabisch (1913a) revisits this topic for northern New Jersey and areas that are part of the current project. While acknowledging the practical impossibility of locating burials except by accident, it is noted that the typical graveyard is "on a warm, sandy hillock near the village" (Skinner and Schrabisch 1913:12). Other likely locations include lowland fields adjoining a village and under a shell heap, or "in and among the hearths of the village itself" (Skinner 1913:12). Schrabisch complements Skinner's observations noting that a relevant source of water could be a river, brook, spring, lake, or swamp. "Forks of brooks" or stream confluences were favored locations "provided the lay of the land and, above all, the opportunities for hunting were such as to promise an easy sustenance (Schrabisch 1913a:35).

Later "early" work in the Delaware Valley and adjacent areas parallels many of the efforts summarized above, in addition to some distinctive innovations. Periglacial and thermokarst features in the New Jersey Coastal Plain that supported wetland habitats were identified as a significant locus of Paleoindian and some Archaic sites (Bonfiglio and Cresson 1978, 1982; Cresson 1978; Kraft and Mounier 1982a:74, 76). Concurrently, Eisenberg (1978:Figure 23) evaluated the environmental associations of six well known Paleoindian sites in the Delaware and Hudson valleys. The majority are associated with surface water, productive plant and animal habitats, well drained ground, and overlook positions.

Cavallo and Mounier (1980) focused on an analysis of existing site data for the New Jersey Pinelands (Coastal Plain) supplementing it with information derived from interviews with artifact collectors and avocational archaeologists. Site age, content, physical condition, and setting were recorded in as much detail as possible. Patterns in associations of site locations and environmental factors were searched for in the process of developing a predictive model for future testing. Four environmental categories account for all known site locations in the study area: tidal wetlands, riverine settings, drainage divides, and thermo-karst basins or areas with internal drainage (Cavallo and Mounier 1980:73). How activities representing specific cultural historical periods are spatially and functionally associated with each of these environmental categories resulted in the definition of study units for future research (Cavallo and Mounier 1980:77-98):

> Paleoindian, Archaic, Woodland and sites of unspecified cultural affiliation – wetlands with focus on islands or eminences within a salt meadow or on the edge of the wetland/meadow;
>
> Paleoindian, Archaic, Woodland, and sites of unspecified cultural affiliation – riverine setting: focus on uplands directly abutting stream margins;
>
> Archaic and sites of unspecified cultural affiliation – drainage divides; and
>
> Paleoindian, Archaic, and sites of unspecified cultural affiliation – basin-like areas with internal drainage: focus on margins of basins.

In order to develop a more precise predictive model a preliminary series of variables was compiled to be used to characterize gridded units, 1,000 meters on a side, within a potential survey area (Cavallo and Mounier 1980:126). Following systematic survey the utility of these variables for predicting site occurrences would be statistically examined. This next step was never taken.

As part of Snethkamp's (1981:194-209, 223-225) study of Late Archaic adaptive processes in portions of the Great Valley of the Delaware and Susquehanna River basins in Pennsylvania the settings of 305 sites were examined. Considered were: general topographic setting; elevation above the nearest water source; distance to closest water source; order of closest stream; distance to second closest water source; order of second closest stream; and aspect/direction of slope. Inadequate representation of springs on USGS maps required the use of supplemental sources of data. Only 25% of sites are located on floodplains with over 50% situated on adjoining terraces and knolls. Slope appears to be an important variable with over 62% of sites having a southern, southeastern, or southwestern aspect. The distance to the nearest water source is less than 150 meters for 83% of sites which represent settings associated with first and second order streams. The height above a water source ranges up to 30 feet (meters) for 71% of sites (Snethkamp 1981:210).

In 1982 Grossman and Cavallo addressed the potential for predictive surveys in New Jersey, suggested how models might be developed, and outlined the biases associated with using existing site data. They cite laudatory examples of model development and use from North America and briefly describe the Cavallo and Mounier approach (Grossman and Cavallo 1982:262-265). Little use is made of the modest number of other endeavors from the Middle Atlantic region in print at that time (e.g., Wells 1981).

Three observations in their work are worthy of emphasis given their intrinsic importance to the development of any model. No matter the environmental variables selected for use they must be represented in mapped, documentary, or photographic form prior to the initiation of field work in a given area. The quality of predictions is thus contingent to a degree on the quality of this pre-existing record. The environmental variables used should exhibit significant spatial variation in the area in which the model will be used. For example, monotonous topography in an area obviates the importance of landform, as a dense drainage net would for distance to surface water. Finally, available environmental data reflects relatively modern conditions so models may not be as relevant for early time periods as they would be for those of the past few thousand years owing to environmental changes.

Marshall (1982:Tables IV-VIII) generated predictions about the frequency of Paleoindian sites expected to occur in New Jersey by physiographic province and what she identified as focal environmental features. Her predictions were based on an analysis of known site distributions and the settlement models in use by others in the Middle Atlantic region. Marshall's work is notable in being both period and function specific while illustrating the variation in predictive variables across geographic space. However, a number of the focal environmental features used in her predictions are somewhat generalized and overlapping to be useful in targeting specific areas within a landscape. For example, in the Ridge and Valley province sites of varying functions are associated with floodplains and river valleys.

A statewide (New Jersey) synthesis of Archaic and Late Woodland archaeology was prepared by Kraft and Mounier in 1982. High ground adjacent to marshlands related to former glacial lakes are noted as favored locations for Archaic settlement in the Piedmont (Kraft and Mounier 1982a:62). Landscapes associated with now extinct springs may be related to earlier Archaic sites (Kraft and Mounier 1982a:71). Thermokarst features appear to be a special draw to

Paleoindian and Early Archaic groups. Of 100 such features examined in the Coastal Plain of Burlington County 95% had site associations (Kraft and Mounier 1982a:74, 76). Springs and the divides between drainage basins are settings attracting Late Archaic activity (Kraft and Mounier 1982a:80). The Archaic and Late Woodland syntheses advocate for the development and testing of predictive models based on surveys that sample all portions of a region, regardless of their anticipated potential for the occurrence of archaeological deposits (Kraft and Mounier 1982a:89; Kraft and Mounier 1982b:173).

In a contemporaneous review of Early and Middle Woodland archaeology in New Jersey Williams and Thomas (1982:124) suggest that in the Coastal Plain the most advantageous locations for riverine-oriented groups "are near the middle to upper reaches of tidal streams at shallow points in the water course and where natural constrictions occur." For the Outer Coastal Plain high site densities should be associated with areas in with multiple habitats and resource diversity (Williams and Thomas 1982:126). Wetland/upland interfaces and potential sources of lithic resources are especially recommended for targeting in future site surveys (Williams and Thomas 1982:132).

The work of Hasenstab (1983, 1984, 1991) represents an early use of GIS to demonstrate associations between environmental data and known site locations in the Passaic River basin of New Jersey. The work was initially part of a CRM project, subsequently developed into a MA thesis (1984), and still later used as the basis of a journal article (1991). The study area was divided up into cells each representing approximately 1.15 acres. Environmental data coded for each cell included: soil type, landform type, slope, soil drainage, agricultural potential, distance to nearest river, distance to nearest river confluence, , distance to nearest tributary, wetland zone class, and current land use and degree of disturbance (Hasenstab 1991:45-51; also see summary of the 1983 work in Kvamme 1989:165). Using existing site locations as a training set univariate statistical tests were used for each variable to determine whether their association with sites was random or non-random (Hasenstab 1991:43). Landform, slope, agricultural potential, and proximity to wetlands were not deemed to be significant predictors. Field testing of the model resulted in the recognition of the importance of wetlands in association with sites.

His study led to the conclusion that existing site inventories can be biased and "should not be relied upon as the basis of archaeological sensitivity models (Hasenstab 1991:40). The bias in this case stemmed from an over-emphasis on the survey of plowed fields and settings near stream confluences. Hasenstab also found that the resolution of USGS 7.5' quadrangles is inadequate for delineating archaeological sensitive areas around wetlands; more precise maps of wetlands are needed for accurate modeling. He also argued that given the uniqueness of the Passaic Basin existing models borrowed from other parts of the region could not be effectively employed (Hasenstab 1991:43).

Modeling by Eveleigh et al (1983; also see Eveleigh 1984a, b) represents the pioneering use of LANDSAT imagery in the region. In conjunction with a logistical regression analysis of combinations of environmental variables associated with known sites, archaeologically sensitive zones were identified (rather than specific site locations) for coastal areas of the Lower Delaware Valley. The work builds on the synoptic approach of Wells (1981) in the Lower Delaware Valley and uses variables similar to those shown to be significant by Wells: distance to closest minor stream; distance to major stream or river; distance to well-drained soil; local gradient; convexity of the landscape; topography related to features such as sinkholes, bay/basins, and river levees; and distance to marsh or wetlands (Custer et al 1986:573; Eveleigh et al 1983:21-22). The use of LANDSAT imagery allows for the mapping and environmental characterization of large areas very quickly and inexpensively, with a resolution of approximately 80 meters (Custer et al 1986:573). Logistical regression was used to analyze the relationship between the locations of known archaeological sites, locations known not to contain archaeological sites, and environmental variables associated with each. The model was then tested in another, larger survey area resulting in the production of a contour map representing three probability classes for archaeological sensitivity: high (>.75), medium (.50 -.75), and low (<.50).

The model and use of LANDSAT data in Delaware was used in subsequent CRM projects (e.g., Custer et al 1984). The approach was brought to a national audience in 1986 (Custer et al 1986). High and medium probability areas that were tested were most closely associated with sites of the Woodland I period (Custer et al 1986:581), circa 3000 BC to 1000 AD (Custer 1984:76-77), and may reflect the impact of sea level rise on the shifting extent of tides, the boundary between fresh and brackish reaches of streams, and the creation of wetlands (see Custer 2018 for review).While some notable ceremonial or ritual sites fell within high and medium probability areas, the Island Field cemetery associated with the time from 500 AD to 1000 AD did not, suggesting that factors other than environmental variables account for the site's location (Custer et al 1986:582-583). The site may be centrally located between habitation sites in nearby high and medium probability zones.

Coincident with the LANDSAT-related projects was the development of a series of management plans for Delaware that utilized existing site data, paleoenvironmental reconstructions, and previous syntheses to model settlement patterns and site settings for individual cultural historical periods (e.g., Custer 1983a, 1986a; Custer and DeSantis 1986). For example, during the Archaic period there is a shift, relative to Paleoindian trends, in the relationship of archaeological sites to lithic sources in Delaware. This is seen in the absence of sites close to the outcrops of the Delaware Chalcedony complex and a greater emphasis on secondary (cobble) sources of lithic materials (Custer 1983a:64). New site settings observed are related to emerging environmental zones associated with the spread of mesic forests, variations in the water table and sea level (Custer 1983a:65). During the Woodland I period there is a reduction in the variety of macro-band base camp settings indicating a shift towards locations with the most reliable surface water and concentrations of resources that could be hunted and gathered. Included are the floodplains of major drainages developing estuarine marshes reflecting continued sea level rise, and well-watered limestone lowlands in the Piedmont uplands (Custer 1983a:106, Figures 17-25, Table 12). Greater variety in the spatial distribution of sites and associated settings is seen during the subsequent Woodland II period (compare Tables 12 and 15).

LeeDecker (1984) examined subsurface sampling procedures used in surveys for the Environmental Protection Agency (EPA) in New Jersey. Sampling schemes, sample size and sample fraction, and field methods are described and evaluated in terms of their ability to affect the probability that archaeological deposits will be discovered LeeDecker 1984:146, 161). Environmental variables used by researchers to predict archaeological sensitivity are mentioned in passing but their utility in the EPA surveys under review is never addressed. Systematic stratified sampling schemes supplemented by purposive sampling are recommended as the most useful approaches to archaeological survey (LeeDecker 1984:167). Testing intervals need to take into account anticipated site types and functions, as these relate to the density and areal extent of cultural deposits (LeeDecker 1984:168-169).

C. Summary of Early Trends

In summary, the initial development and use of models in the region involved both inductive, explanatory, atemporal, and period specific approaches. The potential biases reflected by existing site data bases and the field methods employed in survey projects are commonly acknowledged. There is the recognition that a single, atemporal model will not be effective in all types of environmental zones or physiographic provinces. Local environmental factors and changing Native American lifeways impact the significance of variable combinations. Surface water and a variety of wetland types are viewed as important in many of the models although noted distances from archaeological sites to these features are highly variable. This does not preclude the importance of other variables where surface water and wetlands are involved. The impact of site aspect is highly variable. This variable might prove significant in distinguishing between warm season and cold season use of rockshelters (e.g., Barber 1983:120). The productivity of associated soils appears not to be a particularly useful variable. The greater the number of variables represented by a landscape, the greater the chance that a site might be present. Models seem to be most effective in predicting the relative density of sites in environmental zones rather than pinpointing precise locations on small landscapes.

Both inductive and explanatory/behavioral/deductive models also were used early-on for exploring the archaeological potential of offshore settings, drawing on approaches developed for terrestrial environments (e.g., Barber 1979; Kraft et al 1983; Roberts 1979). The basic recognition of the potential for archaeological deposits predates modeling efforts for offshore zones (e.g., Emery and Edwards 1966).

What I consider to be a compelling observation not widely represented in early endeavors is the requirement that the variables employed in a predictive model be assessed against the environmental background of the areas in which they are to be used. A variable, or combination of variables that are frequently represented and widely distributed in an area to be surveyed cease to have significant predictive power in contrast to areas where they are not frequently represented and widely distributed. This follows from the observation that archaeological sites occupy only a small percentage of the landscapes of an area; there are many more places were sites are not, then places where they are (Ebert 2000:131).

Ranking the potential productivity of landscapes within a survey area and then embedding predictions of specific site locations in highly productive or diverse settings seems to be more effective than simply predicting site locations. The dependent relationship between site locations and environmental variables needs to be statistically affirmed.

D. Subsequent Practices in the Middle Atlantic Region

Succeeding trends in modeling represent qualitative, quantitative, inductive, explanatory/deductive, atemporal, and period specific approaches mirroring the variety of earlier work. No common approach emerges in the region although the variables and variable combinations employed are similar in many cases. There remains, as expected, a close link with settlement pattern studies; variables that are, or could be used in modeling are embedded in settlement pattern studies but are not the focus of such studies. Examples of approaches are summarized below, with a general emphasis on those from physiographic settings of potential relevance to the environmental diversity of the Delaware Valley and the upper portions of the drainage basin.

Studies of upland sites in western Maryland, Virginia, and West Virginia emphasize the important association of spring heads, trails, gaps, sinkholes, overlooks, and areas of maximum habitat diversity with of sites (Lesser and Brashler 1987; Tourtellotte 1987; Wall 1987). These observations reaffirm those of earlier works. In a survey of rockshelters situated on the Appalachian Plateau of Virginia Barber (1987:Table 3) notes distances to surface water ranging up to 800 feet with a mean distance of 283 feet. Site aspect is highly variable, but southern and eastern aspects seem to be the most frequently represented (Barber 1987:162-164).

Stewart and Kratzer (1989) briefly summarize pre-existing locational models with reference to upland areas as part of a site survey focused on a portion of the unglaciated Appalachian Plateau in Pennsylvania. Their approach is inductive and atemporal although the distinction between inductive and deductive/explanatory models is acknowledged. The survey tested assumptions about the utility of a variety of predictive variables concluding that aspect or exposure varies as a useful variable. Stream junctions, springheads, single and converging drainage heads (active and inactive), wetland habitats, saddles between drainage divides, topographic highpoints, and prominent ridgetops are considered to be useful variables. For upland settings "the type of landform appears to take precedence over proximity to surface water in the systemic relationship of predictive variables" (Stewart and Kratzer 1989:28).

Although a number of high probability areas were identified in the areas to be surveyed, few produced archaeological sites (Stewart and Kratzer 1989:Table 1). The linear nature of the study area and the fact that models identify sensitive areas (which can be spatially extensive) and not precise locations were viewed as confounding factors. An example qualifies the issue:

> …archaeological sites are consistently associated with well drained, low relief topography adjacent to a stream junction. This does not mean that if a stream junction is completely flanked by an adequate landform there will be continuous archaeological deposits. One or more sites may ultimately be found but their exact location within the broader zone cannot be consistently predicted. The archaeologist is therefore obliged to examine the entire zone if the validity of the models are to be adequately assessed (Stewart and Kratzer 1989:29).

Of course, testing the entirety of a high probability zone is not often possible in CRM projects given their spatial constraints. Thus, assessing the value of the model, or models employed in CRM survey level projects remains problematic.

As background for a study of site locations in the basin of the South Branch of the Potomac River in West Virginia Neumann (1992) reviews the differences between inductive and deductive/explanatory models, citing examples of each, and noting that one approach is not independent of the other. In addition a typical array of environmental variables including stream meander position, floodplain width, distance to uplands, flow of nearest stream (cubic feet per second), and the flow of next nearest stream were evaluated. Correlations of environmental variables were also assessed resulting in a correlation coefficient matrix.

From an atemporal perspective the vast majority of sites were located within 100 meters of the nearest stream and situated on landforms with slopes of 10% or less with stream terraces favored. The association of stream meander types was variable. As floodplain width decreased site frequencies increased (Neumann 1992:85-87, Table 2, Figures 2-4). Distance from a second stream is 300 meters or less for 76.4% of all recorded sites. This variable includes stream confluences as a subset; 57.5% of sites are located at within 300 meters of a confluence (Neumann 1992:112). Exposure or aspect does not seem to be an overly significant variable (Neumann 1992:112-113).

Interesting co-variations can be noted. As the area of a site increased, the distance to the next nearest stream decreased. As the area of a site increases so too does the flow rate of the nearest stream. The importance of flow rate varies depending upon the cultural historical affiliation of the associated site. The increase of site area correlates with a decrease in the distance to the next nearest stream. Examining site and variable associations by cultural historical period revealed patterns that might reflect site function, a dichotomy between what probably represent warm season and cold season occupations, or seasonal transhumance between lowlands and uplands (Neumann 1992:87-118).

Using site data available for Pennsylvania in 1996, Carr and Keller assessed the topographic setting of sites by physiographic zone. For each zone the greatest percentages of sites are associated with the settings shown in Table 2. Other settings considered in the analysis include beaches, rises in floodplains, lower slopes, mid-slopes, hilltop, upland flat, hilltop, ridge top, saddle, island, and hill slope (Carr and Keller 1998:Figure 7). Upland saddles, Pleistocene beaches, marl soils, highly fertile soils, areas within 200 meters of a third or higher order stream, bedrock formations associated with high frequencies of rockshelters, and bedrock formations representing useful lithic materials are considered to be especially important variables in identifying areas requiring archaeological survey (Carr and Keller 1998:10, Figure 17).

Relevant to the Delaware Valley in varying degrees are the Coastal Plain, Piedmont Uplands, Triassic Lowlands, Reading Prong, Great Valley, Appalachian Mountain, Pocono Plateau, and Glaciated Low Plateau environmental zones (Carr and Keller 1998:Figures 3, 4). Data for the Reading Prong, Great Valley, Appalachian Mountain, Pocono Plateau, and Glaciated Low Plateau zones are reconsidered in the discussion of the Upper Delaware project area later in this report.

TABLE 2
Topographic Settings Associated with the Greatest Percentage of Sites for Physiographic Zones in Pennsylvania*

Physiographic Zone	Topographic Setting	Percentage of Sites Represented
Coastal Plain	stream terraces	66%
Piedmont Uplands	stream benches	42%
Conestoga Valley	stream benches	28%
Conestoga Valley	hill/ridge toes	26%
Triassic Lowlands	floodplains	23%
Triassic Lowlands	stream terraces	25%
South Mountain	stream benches	48%
Reading Prong	stream terraces	25%
Reading Prong	stream benches	21%
Great Valley	stream terraces	25%
Great Valley	stream benches	32%
Appalachian Mountains	floodplains	48%
Appalachian Mountains	stream benches	24%
Pocono Plateau	floodplains	30%
Allegheny Mountains	floodplains	25%
Glaciated Low Plateau	floodplains	49%
Pittsburgh Plateau	floodplains	20%
Pittsburgh Plateau	stream terraces	23%
Allegheny High Plateau	floodplains	36%
Appalachian Plateau	floodplains	26%
Appalachian Plateau	stream terraces	38%
Eastern Lake Section	stream terraces	41%
Eastern Lake Section	upland flats	33%

*Abstracted from Carr and Keller (1998:Figures 4, 7)

A 2001 study (Chiarulli et al) of upland sites in select watersheds of Pennsylvania is a reaction to the Carr and Keller (1998) analysis and the development of priorities for survey and settlement pattern research (Miller 2001a; also see Stewart 2000). The selected watersheds (Conemaugh River-Blacklick Creek, Conodoguinet, and Brandywine) provide a general west to east sample of landscape diversity in the state, ranging from the unglaciated Allegheny Plateau section of the Appalachian Plateaus province, to the Great Valley and Appalachian Mountain sections of the Ridge and Valley province, and the Piedmont Uplands and Triassic Lowlands of the Piedmont province. Components of the environmental setting of sites are among the issues addressed in the compilation.

Chiarulli (2001) reviews a variety of projects relevant to an understanding of site locations and settlement patterns in the Conemaugh-Blacklick watershed. Summarizing a generalized predictive model developed by Verna Cowin, Chiarulli (2001:20) notes that among other things upland sites are associated with hilltops, benches, saddles, and well drained soils. Floodplain and terrace sites tend to occur near stream junctions, including small intermittent runs originating from springs. The most substantial sites are located in settings providing access to lithic resources and from which a variety of habitats could be exploited.

Regarding predictive modeling, a study of the Crooked Creek drainage (Neusius and Neusius 1989; Neusius and Watson 1991) is given special attention in Chiarulli's review. A grid of 300 meter squares/quadrats was overlaid on the area to be surveyed and each scored on the basis of the state of a given variable. For example, the presence of surface water within a square scored three points, water in one or more adjacent units scored two points, water one unit away one point. Other variables/variable states contributing to a quadrat's score included topographic setting, slope, aspect, proximity of Native American paths/trails, and soil suitability (Chiarulli 2001:Table 4). Quadrats were assigned one of five different probabilities for the occurrence of sites: sites are highly probable to occur; sites are probable; sites are possible; site occurrence is improbable, site occurrence is highly improbable. A random sample of quadrats were selected for survey from each of these categories. Shovel tests and surface survey were employed in the field survey.

The results of the survey were inconclusive; "the study was not successful in developing a predictive model for the location of upland sites " (Chiarulli 2001:24). One of the problems identified with the Crooked Creek model is that the size of the quadrats was so large that multiple micro-environmental habitats were encompassed by each (Chiarulli 2001:26); presumably the scoring protocol was not sensitive to this variation making it impossible to evaluate its predictive value.

Perazio and Meyer (2001) focus more heavily on modeling in their study of the Conodoguinet watershed and employ a model previously developed for the Pocono Plateau in the Upper Delaware Valley. Important variables in the Pocono model are: topography, slope, aspect, distance (both horizontal and vertical) to freshwater sources, distance to stream confluences, soil drainage, and soil productivity (Perazio and Meyer 2001:144). Micro-topographic variation is seen as a key factor in assessing site potential in the Poconos. "Small rises near resource concentrations (e.g., wetlands) appear to have attracted increased aboriginal activity" (Perazio and Meyer 2001:159).

In applying the Pocono model to the Conodoguinet watershed they found that the distribution of sites by landform, setting, and time period shows no discernible patterning (Perazio and Meyer 2001:159). Aspect and distance to a stream confluence are not obviously useful variables (Perazio and Meyer 2001:160-161). However, 90% of sites occur within 100 meters of water (Perazio and Meyer 2001:164). The weak or nonexistent patterning in the data is partially attributed to the small sample of sites in the watershed (Perazio and Meyer 2001:144). The ability to assess micro-topographic variation prior to field inspections presents another difficulty in evaluating the utility of the model (Perazio and Meyer 2001:159).

The Piedmont Uplands and a portion of the Triassic Lowlands of the Brandywine drainage of eastern Pennsylvania were the focus of a study by Siegel et al (2001). Of all of the topographic settings with which sites are associated stream benches account for the greatest percentage (45.95%) in the Brandywine Creek watershed, followed by terraces at 20.38% (Siegel et al 2001:Table 2). This parallels trends noted by Carr and Keller (1998) for the Piedmont Uplands and Triassic Lowlands of Pennsylvania in general. Where cultural historical affiliation can be determined, the greatest number of Middle Archaic through Early Woodland sites in the Brandywine drainage occur on stream benches. Middle and Late Woodland sites are best represented by stream bench and stream terrace/ancient floodplain settings (Siegel et al 2001:Table 6). The location of significant, potentially significant, and otherwise informative prehistoric sites on stream benches is "the single most compelling finding of this study" (Siegel et al 2001:221).

Compelling is a recommendation that CRM reports need to consistently assess the value of the predictive models used in a given survey owing to their frequent in contemporary work (Siegel et al 2001:212). Sadly, a similar recommendation was made long before the 2001 study (Custer 1986b:44) and post-field model evaluations remain an inconsistent component of survey reports for many portions of the region to the present day.

Observations about the environmental variables associated with sites are scattered throughout a review of archaeological projects conducted in the Upper Juniata River basin in Pennsylvania (MacDonald et al 2003). The basin is part of the Appalachian Mountain section of the Ridge and Valley province. Observations include the association of sites with: spring heads in uplands and along narrow portions of terraces along larger streams; and ridgetops overlooking stream confluences (MacDonald et al 2003:37, 38). Trends associated with specific cultural historical periods are discussed below.

The continuing importance of the use of GIS technology in the development of a predictive model is reflected by the work of Duncan and Beckman (2000) focused on a portion of the Monongahela River Valley in southwestern Pennsylvania. The authors have considerable experience in the formulation and use of predictive models (e.g., Duncan 2002; Duncan et al 1996, 1999a, 1999b).

Their generally inductive model was developed using environmental variables and known site locations, and then tested in area subjected to 100% survey (Duncan and Beckman 2000:36). Primary data used in model formulation included: historically documented Indian trails, roads and other disturbance factors; hydrologic features (e.g., rivers, streams, lakes, wetlands and springs); soils; and a digital elevation model used to identify a number of topographic features (saddles, peaks, vantage points and rims). Secondary data sets such as slope, aspect, and distance to water were developed within the GIS (Duncan and Beckman 2000:36-42). Cost-distance analysis was performed using slope as the cost surface for water, Indian trails, fifth-order drainage divides, saddles, and vantage points. Here the assumption is that cost distance better reflects the effort expended to reach a location with useful resources (Duncan and Beckham 2000:42).

Statistical comparisons (exploratory and univariate) of the distributions of variables for *both* site and background location samples honed the number of variables under consideration from 70 to 26. Logistical regression was employed to redefine and adjust the relative weights assigned the variables used to score the site potential of each cell (30 meters square) in a grid superimposed on the project area. The model was then tested against a sample of 2082 site and random background cells resulting in a "predictive surface applied across the entire study area" (Duncan and Beckman 2000:45).

Duncan and Beckman (2000:55-56) conclude that the process used is flexible enough to be employed in any geographic area without presuming that the value of the variables used in one area will remain the same in another. Their model is atemporal; the quality of available data for individual sites precluded any functional or temporal considerations. They recognize, as have others, the problematic assumption that current measurable characteristics of the environment are relevant to prehistoric contexts, and that available data cannot account for other influences on site locations such as sociopolitical factors.

Miller (in press) summarizes aspects of predictive models in use in the Susquehanna River basin of Pennsylvania noting that all consider distance to water as the primary variable. The Pennsylvania Archaeological Site Survey files indicate that 80-90% are within 150 meters of water but this trend breaks down when specific geographic areas are examined. An evaluation of known sites in the Nittanny Valley (Ridge and Valley province) revealed that 63% are found within 150 meters of water (Miller and Dinsmore 1990). A study of well surveyed Piedmont Lowlands portions of the Conestoga Valley (Miller 2002) concludes that only 40% of sites conformed to the distance parameter of 150 meters. In addition, predictive value could not be assigned to the variables of slope, aspect and soil type.

Custer (1988) provides a complementary view of sites in the Piedmont Uplands and Piedmont Lowlands of eastern Pennsylvania, focusing on lithic scatters. Lithic scatters are defined as generally covering less than 100 m^2 and producing fewer than 30 flakes, and fewer than five bifaces or projectile points (Custer 1988:31). In the Piedmont Uplands 67% of sites are located within 40 meters of surface water; 63% of sites in the Piedmont Lowlands are located within 40 meters of surface water (Custer 1988:32). The aspect of sites in both areas reveals no particular trends.

Harris (2013a) completed an extensive review of the use of predictive models as part of the development of a statewide predictive models for Pennsylvania. His review draws largely on CRM technical reports on file with the Pennsylvania State Historic Preservation Office, and less so on specific examples from other areas and in the published literature. The foundational references for the project consisted of 32 CRM reports that presented formal predictive models and a means to evaluate their results. Nine of these were considered to represent creative methodologies and important contributions to modeling, and were subjected to a detailed evaluation.

The variation in models is organized by Harris (2013a:8-20) into types based on: how they are derived (deductive/inductive); the quality and quantity of environmental data; the quality and quantity of data related to the settings of known sites; the degree to which variables are related to landscape measurements and weighted in the assessment of survey landscapes; the degree to which they rely on an analysis of known site locations; the degree to which the sensitivity assessment of a landscape can be replicated; and the use of statistical techniques, including regression analysis to quantify patterns. The reader should consult Harris's report for a discussion of the pros and cons of each type of model.

Table 3 lists the variables used in the models reviewed by Harris. Slope, water, landform, and soil are the most commonly used variables in the models that were evaluated. Distance measurements follow in frequency of usage with variables of topographic aspect, hydrology network variables such as confluences and stream rank, and solar insolation less frequently employed (Harris 2013a:89). Commonality of use does not necessarily translate into the effectiveness of any given variable in predicting site locations. Determining which of the variables are most successful in predicting sites requires testing them against non-site locations

TABLE 3
Environmental Variables Employed in Models Reviewed for
Pennsylvania Statewide Predictive Model Development*

VARIABLE CLASS	RELATIVE PERCENT OF USE IN REPORT SAMPLE
Soil Characteristics (Drainage, Texture, Type)	75%
Topographic Slope	75%
Topographic Landform	70%
Elevation above Water	40%
Cost Distance to Confluence	30%
Cost Distance to Streams and Water Bodies	30%
Distance to Streams and Water Bodies	30%
Surface Geology	30%
Cost Distance to Native American Trails	20%
Depth to Bedrock	20%
Distance to Native American Trails	20%
Stream Order	20%
Topographic Aspect	20%
Wildlife Suitability	20%
Cost Distance to Topographic Saddles	15%
Distance to Drainage Divides	15%
Distance to Steam Confluence	15%
Number of Frost Free Days	15%
Solar Insolation	15%
Local Topographic Relief	15%
Cost Distance to Drainage Divides	5%
Cost Distance to Headwaters	5%
Cost Distance to Lithic Sources	5%
Cost Distance to Peaks	5%
Cost Distance to Vantage Point	5%
Cost Distance to Wetlands	5%
Depth to Ground Water	5%
Elevation	5%
Flood Frequency	5%
Local Stream Density	5%

*Source: Harris 2013a:Table 40

in the broader environment and determining how background data influences their particular contribution to the success or failure of a model (Harris 2013a:90-91, 96). Many of the variables in Table 3 are found in the models already considered in this report. Depth to bedrock, depth to ground water, flood frequency, and local stream density are additions to those previously considered. I find the consideration of local stream density to be compelling in that it could impact the predictive value of proximity to surface water and stream junctions. Few models attempt to explain variation in site locations using cultural variables (Harris 2013a:89).

The assessment of the nine selected projects examined the assumptions of the models, how variables were selected and whether they were tested against non-site environmental background data, and the effectiveness and performance of the model. The actual observed presence/absence of archaeological sites versus the predicted presence/absence generated from the model was examined. The Kg (Kvamme Gain Statistic - Kg) was used to measure model efficiency. "It is a relative measure of a model's balance between the correct prediction of site locations versus the size of the area within which sites are predicted" (Harris 2013a:27).

> The equation used to derive the statistic is the percent of the modeled area predicted as likely to contain sites divided by the percent of the site sample that is predicted correctly within that area, subtracted from 1. A Kg ranging between 0.5 and 0.8 is typical for models that are parsed so as to balance the correct prediction of sites against the disadvantages of predicting an unduly large area to contain sites. (Harris 2013a:28).

A single project involving the Upper Delaware (Bailey and Dekin 1980) is included in these evaluations and is discussed in a report section below.

Where appropriate statistical methods are employed the significance of variables can be assessed, as is the case in a small number of the projects evaluated by Harris (2013a:91, Table 50). Hart's (1994) models for the Lake Erie Plain and Glacial Escarpment physiographic sections (Harris 2013a:54-61) are singled out as one of best examples of a regression model that also employed GIS. A linear project by Whitley and Bastianini (1992) which almost crosses the entire width of southern Pennsylvania is notable for relatively weighting each variable based on the total difference between sites and background values within all classes of that variable. That is, selected variables were tested against background environmental values to prove or disprove a significant correlation between site locations and those values (Harris 2013a:46-53). A number of other studies are notable for taking this significant step of statistically comparing site locations against non-site locations or environmental background (i.e., Duncan et al 1996, 1999a; Duncan and Schilling 1999a, b; Miller 2002; Miller and Kodlick 2006).

The review concludes (Harris 2013a:96-101) that no single study stands out as the best (or worst) example of how to create an archaeological predictive model. No single model is appropriate for use throughout the state; different environments and data sets require tailoring a model to specific situations. Regardless of the number or nature of environmental variables employed in a model, they must be tested against the environmental background of a project area. To avoid problems in the evaluation of models and their use in areas beyond where they were formulated, certain standards should be adhered to:

> At a minimum, specific documentation should include the following: model goals; theoretical orientation and justification; variables selected for evaluation; variables accepted for the model and how they were tested; modeling steps and

> details such as weighting schemes or regression metrics depending on the model type; the percentages of the study area covered by each sensitivity class and the classification of site and non-site areas into each class; the evaluation of the findings; and the assumptions and limitations that guide the implementation of the final model (Harris 2013a:96-97).

A subsequent series of reports define the environmental regions of Pennsylvania for which predictive models will be developed, presents a pilot study of model development and testing, and detail the construction of models specific to 10 different environmental zones. Environmental divisions were designed to: reduce the environmental variation within each model; model groups of site locations that are more geographically related; and better organize the modeling process and computability (Harris 2013b). Landscape divisions were formulated to decrease certain types of environmental variation while at the same time attempting to distribute the known site data points enhancing the best degree of regression model fit and performance (Harris 2013b:1).

The process employed physiographic provinces and sectional divisions, major and minor watersheds (n=104), and "physiosheds" (n=250). Physiosheds are combinations of physiographic sections and watershed boundaries. Since variation of landform geomorphology within a section is less than within major watersheds, physiographic section boundaries were used as the primary modeling region boundary yielding 10 modeling regions (Harris 2013b:2). Within each of the 10 regions, models were built at the scale of physiosheds and then aggregated into larger regions (Harris 2013b:6-7, 16). Table 4 outlines the gross characteristics of the 10 modeling regions.

Harris (2014) details how different classes of models were created and tested for a pilot study area situated in Blair, Centre, Clearfield, and Clinton counties, Pennsylvania. Sections of the Appalachian Plateaus and Ridge and Valley physiographic provinces (portions of modeling regions 1-5) are represented (Harris 2014:Table 2; see Table 4, this report). This approach acknowledges that only portions of Native American settlement patterns that were influenced by environmental factors, or cultural factors that have a significant environmental association, are being modeled (Harris 2014:3).

Judgmentally weighted attributes of slope and distance to streams were used to create a class of models (Class 1) for areas that lack a sufficient sample of documented sites which could serve as a basis for evaluating environmental settings. Slope and distance to water are argued to represent the most basic environmental constraints in relation to habitable locations (Harris 2014:9-10). A proportionally weighted model class (Class 2) is applied to areas with more than 10 documented sites and uses the location of known sites to guide the selection and weighting of variables and creation of sensitivity values (Harris 2014:11). The distribution of sensitivity values derived from this process is compared with environmental background data and a Kg statistic derived (Harris 2014:13). Model Class 3 is a collection of models that are more statistically based than those of Class 12, are geared toward regression analysis, and require a high degree of data and effort to create (Harris 2014:14). Areas appropriate for this type of modeling must contain at least 10 previously documented sites.

TABLE 4
Breakdown of Environmental Divisions Used in the Development of Statewide Predictive Models For Pennsylvania*

Modeling Region	Physiographic Province	Physiographic Section	Major Watersheds	Number of Physiosheds	Prehistoric Sites per Square Mile
1	Appalachian Plateaus	Waynesburg Hills Pittsburgh Low Plateau	Allegheny Monongahela Ohio	34	0.59
2	Appalachian Plateaus	High Plateau Northwestern Glaciated Plateau	Allegheny Lake Erie Ohio	16	0.35
3	Central Lowlands	Eastern Lake	Lake Erie	1	0.63
4	Appalachian Plateaus Ridge and Valley	Allegheny Front Appalachian Mountain	Potomac Susquehanna	37	0.26
5	Ridge and Valley	Susquehanna Lowland Anthracite Upland	Delaware Susquehanna	28	0.31
6	Appalachian Plateaus	Deep Valleys Glaciated High Plateau	Allegheny Genesee Susquehanna	21	0.07
7	Appalachian Plateaus Ridge and Valley	Glaciated Low Plateau Anthracite Valley	Delaware Susquehanna	32	0.19
8	Ridge and Valley New England	Blue Mountain Great Valley South Mountain Reading Prong	Delaware Susquehanna Potomac	36	0.69
9	Piedmont	Gettysburg-Newark Lowland Piedmont Upland Piedmont Lowland	Delaware Susquehanna Potomac	40	0.82
10	Coastal Plain	Lowland and Intermediate Lowland	Delaware	5	0.10

*Abstracted from Harris 2013b:Tables 3-5, 7

The performance of Class 1 models was difficult to evaluate in the pilot study. Proportionally weighted models (Class 2) more accurately describe the locations of archaeological sites within each region, but Class 3 models represent the ideal but are contingent on the existence of sufficient data on known site locations (Harris 2014:39-78). The final ensemble of 10 sub-models correctly classified 85% of known archaeological sites into either high (72% of sites) or moderate (13% of sites) sensitivity areas. "Compared to random survey, the chances of finding a site in high or moderate sensitivity areas are 5.56 times greater" (Harris 2014:79).

Thirty separate models for sub-regions within Modeling Regions 1-3 (see Table 4, this report) followed procedures tested in the pilot study involving the examination of the settings and components of 755 prehistoric archaeological sites, and the development of 89 individual environmental variables. The 89 variables examined include features of topography, hydrology, and distance to historically documented trails (Harris et al 2014a:Appendix B). Their significance for each of the designated sub-areas was calculated (Harris et al 2014a:Appendix C, D). The protocol also involved:

> the testing of each of these variables against the environmental background of each subarea, the parameterization and validation of a logistic regression, adaptive regression splines, and random forest models for each subarea, final model selection based on error estimate results, the establishment of numerous potential thresholds based on variable criteria, and, finally, the application of selected thresholds and mosaicking of 30 separate subarea models into the final model for each region (Harris et al 2014a:42, 97).

The ensemble model of regions 1-3 regions:

> correctly classifies all archaeological sites within 30.8 percent of the study area, for a Kg of 0.692. In actuality, the model is capable of correctly predicting the location of all archaeological sites and minimizing the site-likely area to on average 5 percent of the study area, but the selection of a low end threshold for the site-likely area was intentionally set to approximately 33 percent of the study area. Compared to a random survey, the chances of finding a site in the combined high and moderate sensitivity area are 3.252 times greater" (Harris et al 2014a:97).

The chances of finding a site in combined high and moderate sensitivity areas are 3.252 times greater compared to a random survey (Harris et al 2014a:97).

As with the process for Modeling Regions 1-3, the development of models for regions 3-6 (see Table 4, this report) represented an adaptation of the pilot study methodology (Harris et al 2014b). Individual models (n=131) were created and evaluated for the 36 subareas with regions 4-6, eventually resulting in 36 models specific to each sub-area. In addition to the model types used in the analysis of regions 1-3, a proportionally weighted model also was used owing to the data quality in some areas (Harris et al 2014b:83). Aspects of area soils were considered in addition to variables representing features of topography, hydrology, and distance to historic trails (Harris et al 2014b:Appendic C, D). Ninety-three variables were identified with final selections based on a variable's ability to discriminate site locations from background locations (Harris et al 2014b:60). The settings and components of 283 prehistoric archaeological sites were evaluated for this effort (Harris et al 2014b:42). The ensemble model created from those of the 36 sub-areas:

> correctly classifies 95.2% of known site-present cells within 29.9% of the study area, for a Kg of 0.685. In actuality, the model is capable of correctly predicting the location of all archaeological sites and minimizing the site-likely area to a much smaller percent of the study area, but the selection of a low end threshold for the site-likely area was intentionally set to approximately 33% of the study area. Compared to a random survey, the chances of finding a site in the combined high and moderate sensitivity area are 3.179 times greater (Harris et al 2014b:83).

Portions of the development and implementation of Pennsylvania's statewide predictive models that are relevant to the Delaware Valley and the Upper Delaware project area are examined in report sections below.

The methods, results, strengths and weaknesses of the project to develop statewide models is summarized in Harris et al (2015). The models statistical base, computational efficiency and replicability, capacity to consider a wide array of variables, and widespread geographic applicability are notable strengths. A notable weakness is that each model relies on existing data regarding site settings which is undeniably biased and likely not representative of an adequate sample of the range of environments in which sites occur in any individual modeling region (Harris et al 2015:89). Updating the models as new sites are located is essential to their improvement.

Relatively recent examples of models used in bay and ocean shoreline surveys include the work of Lowery (2001, 2003), Bates and colleagues (Bates et al 2018; Farrell et al 2018) in Virginia. Lowery's (2003) settlement pattern/predictive models use aspects of the interrelated variable classes of soil type, slope, proximity to water, and type of water (fresh, brackish, or saline). All are considered against the backdrop of marine transgression, tidal and other processes affecting shorelines and near-shore environments (Lowery 2003:100-174; also see Lowery 2001). The nature of the environment in an area is recognized as having an impact on the ability to predict site locations.

> The uniformity of the landscape can create a situation where there is an overabundance of one or a limited diversity of natural resources available to humans. In other words, a uniform landscape would not be ecologically diverse. Therefore, the low ecological diversity in an area may make it harder to predict prehistoric sites in those regions (Lowery 2003:118).

Climate change is a factor influencing the environmental diversity, potentially cycling the same area between being ecologically diverse and more uniform; a single archaeological site may be associated with multiple ecological settings through time (Lowery 2003:233).

Nine settlement pattern models which predict the location of sites are presented and reflect the complex inter-relationships of the variables that Lowery considers. An example is the Point Focus Settlement Pattern where sites "located on points of well-drained land surrounded by broad tidal rivers, creeks, or estuaries. Brackish or saline resources are typically located near the shoals adjacent to the shoreline. Broad or fringing tidal marshes are usually adjacent to the shoreline" (Lowery 2003:127). Areas to be surveyed were designated as having a high, medium or low probability for the occurrence of sites but how these sensitivity classes were created, and their relationship to the nine settlement models, is not detailed. An accuracy level of 95% is claimed for the model. The claim is based upon the observation that of the 44 sites located during the survey, 42 occurred in areas predicted to contain sites (Lowery 2003:iv, Table A.9). No data is provided regarding the overall number and area of locations predicted to contain sites for comparison.

The more recent work of Bates and colleagues (Bates et al 2018; Farrell et al 2018; Rose et al 2017) along the Chesapeake Bay and adjacent drainages combines a detailed survey of shoreline erosion with the development of a predictive model (Vulnerability Potential and Condition Model). The extent of shoreline change from 1937 to 2013 was tracked at over 300 historic and prehistoric archaeological sites and used to quantify annual shoreline change rates. The predictive model uses the environmental setting of known sites (geology, soil type, clay content, corn productivity, elevation, aspect, slope, and proximity to shoreline, proximity to stream headwaters, proximity to marshes, marine wetlands, freshwater wetlands, and riverine wetlands) and historical accounts of the environmental setting of native villages to assess the potential location of additional sites. The Weights of Evidence tool in the Spatial Data Modeler extension (Arc-SDM) for ArcGIS was used to quantify the spatial relationships between known prehistoric archaeological sites and environmental variables and assess their influence on site occurrence (Rose et al 2017:96-153).

The model was successful in predicting known and unknown (prior to survey) sites. The success of the model is partially attributed to the large number of shoreline sites that were used as training points "resulting in a probability map that is well-suited for predicting site locations in close proximity to the Bay and its major and minor tributaries, but likely less effective when it comes to predicting site locations in upland areas" (Rose et al 2017:153). In comparison with Lowery's predictive models for similar environmental areas this approach is replicable and supported by statistical analysis.

Assessments of the vulnerability of shoreline areas builds upon previous research (e.g., Lowery 2008; Lowery et al 2012) and included areas previously evaluated by Lowery 2008). A comparison of the results of the new study with Lowery's previous work reveals similar results for many sites/areas, "but limitations to his model exist in its inability to quantify shoreline movement and predict site outcomes" (Rose et al 2017:87-88). By site outcomes is meant the timing and degree of impact of shoreline processes on archaeological sites.

Considering submerged sites in Chesapeake Bay Blanton (1996) notes that a working knowledge of the effects of sea level rise, erosion, and other coastal processes must be considered as part of evaluating the potential for sites. Based on sites located by the dredging of watermen he concludes that nearly all offshore sites are situated at the upper edge of submerged terraces and reflect the locations typically targeted by terrestrial models (Blanton1996:204, 210, Table 11-2). In a review of offshore studies relevant to the Mid-Atlantic Bight, Merwin (2003, 2010) notes the applicability of variables used in terrestrial predictive models in conjunction with a GIS.

Mentions of environmental variables associated with sites are embedded in a variety of discussions of settlement patterns organized by cultural historical period and representing many portions of the Middle Atlantic Region (e.g., Adovasio et al 1998; Custer 1989, 1990, 1996; Hantman and Klein 1992; Klein and Klatka 1991). For the Paleoindian period, a number of studies reaffirm the observations of site and environmental associations made in earlier works, supplemented with additional data and analysis (e.g., Custer 1985, 1989:93-109, 1996:100-126; Gardner 1989; Turner 1989).

Custer (1985) assessed the potential for sites of individual cultural historical periods by environmental zone for Pennsylvania (Coastal Plain, Fall Line, Piedmont Uplands, Lancaster-Frederick Lowlands, and Triassic Uplands). He explicitly lists environmental variables associated with different types of Paleoindian sites, details not always provided for other cultural historical periods. Significant variables include: lithic sources; level ground associated with surface water closest to a lithic source; level ground with a southern exposure associated with a stream confluence within 1-2 km of a lithic source; level ground with a southern exposure associated with a stream confluence and game attractive locations; well drained ground adjacent to swamps, bogs, sinkholes, and other game attractive locations within 3 km of a base camp (Custer 1985:Table 3.3).

In addition to addressing the debate over the importance of "lithic scatters" Custer (1987, 1988) summarizes Middle Atlantic region trends in site locations through time emphasizing the dramatic increase in setting diversity represented by Late Archaic localities in comparison with those of earlier periods (Custer 1987:178). Paleoindian/Early Archaic and Middle Archaic sites are found in a more restricted range of geomorphological settings with extensive swamps and springhead bogs emphasized (Custer 1988:32; 1996:120, 122, 124).

In a review of Paleoindian data for Pennsylvania, Carr and Adovasio (2002) provide data for site settings in different physiographic provinces and compare observable patterns with those of later time periods. Paleoindian site settings differ in some respects between physiographic provinces/sections and are contrastive with those of later periods (Carr and Adovasio 2002:36-39, Tables 3-6). Paleoindian sites are more heavily focused on riverine settings than those of the Early Archaic and sites associated with bifurcate biface types (Carr and Adovasio 2002:Figure 22). Tables 5 and 6 provide examples of other contrasts. Carr (2018 personal communication) maintains that distance to a stream confluence is a better indication of a site's position within a drainage basin. The differences in the number of sites per category in the tables reflects the accumulation of data over recent years. It is suggested that Paleoindian sites in the Piedmont and Ridge and Valley provinces are located within higher order stream basins and closer to the main stem of the drainage in comparison with sites of later periods (also see Carr and Adovasio 2002:36). Table 7 summarizes similar data irrespective of physiographic province.

MacDonald et al (2003) synthesize existing site data for the Upper Juniata River Basin of the Appalachian Mountain section of the Ridge and Valley province in Pennsylvania. Distance to water and distance to stream confluences were tracked among other variables. Table 8 highlights trends through time regarding distances to streams and confluences. Paleoindian sites are associated predominantly with floodplains or benches of streams and within 100 meters of water, and within 800 meters of a stream confluence (MacDonald et al 2003:48-50). Similar patterns are noted for Early and Middle Archaic sites (MacDonald et al 2003:57-58, 66).

The mean distance to confluences for a Late Archaic sites is 568.7 meters; for Transitional Archaic sites the distance is 610.5 meters. These are two of the highest mean distances to confluences of any cultural historical period. This raises the possibility that immediate access to water and stream confluences was actually less important for Transitional period groups then earlier Archaic and Paleoindian peoples (MacDonald et al 2003:105). These data compare with that summarized by Carr (2015:Figure 3.4) for all areas of Pennsylvania (see

Table 7, this report). The vast majority (97.4%) of Late Woodland sites occur less than 400 meters from a stream (MacDonald et al 2003:161).

TABLE 5
Average Distance to Stream Confluence for Select Time Periods and Physiographic Zones, Pennsylvania*

Physiographic Zone	**Paleoindian**		**Early Archaic**		**Bifurcate Components**		**Broadspear Components**	
	Number of sites	Distance (meters)	Number of sites	Distance (meters)	Number of sites	Distance (meters)	Number of sites	Distance (meters)
Piedmont	35	645	31	675	105	670	96	690
Great Valley	16	793	16	781	66	687	89	623
Ridge and Valley	44	490	58	587	123	611	157	659
Glaciated Plateau	34	666	39	724	65	802	59	646
Unglaciated Plateau	94	633	138	733	313	681	39	610

*Data derived from Carr and Adovasio 2002:Table 4. Distances are recorded in feet in the published table but should have been recorded as meters (Carr 2018 personal communication).

TABLE 6
Average Stream Order of the Nearest Confluence to Sites by Physiographic Zone and Time Period, Pennsylvania*

Physiographic Zone	**Paleoindian**		**Early Archaic**		**Bifurcate Components**		**Transitional Archaic**		**Late Woodland**	
	Number of sites	Stream Order	Number of sites	Stream Order	Number of sites	Stream Order	Number of sites	Stream Order	Number of sites	Stream Order
Piedmont	39	4.59	34	3.94	147	3.97	512	3.66	467	4.01
Great Valley	27	3.44	25	3.80	91	3.88	276	3.48	257	3.50
Ridge and Valley	61	5.31	79	4.42	155	4.90	307	4.99	396	5.06
Glaciated Plateau	69	4.46	47	4.53	99	4.53	227	4.93	447	5.11
Unglaciated Plateau	112	3.90	149	3.71	418	3.74	168	4.24	691	4.13

*Data derived from Carr and Adovasio, in press.

TABLE 7
Relation of Sites to Streams and Stream Confluences in the
Susquehanna, Potomac, and Delaware River Basins, Pennsylvania*

Cultural Period	Average Distance to Nearest Stream/Water (meters)	Average Distance to Stream Confluence (meters)	Average Order of Nearest Stream
Paleoindian	75.5	571.69	3.2
Early Archaic	77.51	602.93	2.8
Middle Archaic	76.3	682.6	2.7
Late Archaic	73.09	745.78	2.4
Transitional	73.01	708.25	2.6
Early Woodland	69.95	662.73	3.2
Middle Woodland	72.35	738.71	3.1
Late Woodland	78.1	693.01	3.1

*Data abstracted from Carr 2015:Figures 3.4, 3.5

TABLE 8
Relation of Sites to Streams and Stream Confluences in the
Upper Juniata River Basin, Pennsylvania*

Cultural Period	Number of Sites	Distance to Nearest Stream (meters)			Distance to Stream Confluence (meters)		
		Range	Mean	Median	Range	Mean	Median
Paleoindian	10	0 - 310	64.3	40	60 - 800	343	270
Early Archaic	10	10 - 200	67.3	53	100 - 600	303	255
Middle Archaic	31	0 - 360	60.6	60	5 - 2000	588.5	500
Late Archaic	74	0 - 540	92.9	130	10 - 4040	604.6	520
Transitional	36	0 - 540	90.8	70	0 - 2650	627.2	450
Early Woodland	14	0	NA	NA	0 - 2520	608.5	400
Middle Woodland	10	0 - 140	45	40	40 - 2160	603	460
Late Woodland	77	---	---	---	---	---	---

*Compiled from MacDonald et al 2003:120, Tables 5, 8, 15, 20, 27, 32, 36; raw data not reported for Late Woodland sites; 0 = stream or confluence adjacent to site

For the Maryland Blue Ridge and Great Valley provinces Stewart (1992) argues that Kirk components of the Early Archaic reflect the use of a broader range of environments than the pattern attributed to all types of more ancient Early Archaic and Paleoindian sites. Considering Pennsylvania as a whole Carr (1998a:59, Table 3) notes that Early Archaic sites are nowhere near as focused on floodplain related settings as are Paleoindian sites. It is only in the Susquehanna Valley that the setting of Early Archaic sites show an appreciable emphasis (66% of known sites) on floodplain-related settings. In the Pennsylvania Piedmont Early Archaic sites are often located near poorly drained settings (Raber et al 1998:126).

For the Ohio, Delaware, Lower and Upper Susquehanna drainages in Pennsylvania the average distances to the nearest perennial stream confluence for Early Archaic sites fall between 524 meters and 694 meters. Sites in the Delaware basin have the lowest average distance at 524 meters. Sites with bifurcate components range between 629 meters and 799 meters, the average distance is lowest (629 meters) for the Upper Susquehanna drainage (Bergman et al, in press).

Parker (1990) analyzed a sample of 67 Early and Middle Archaic sites from the Appalachian Valley, Blue Ridge, and Piedmont sections of Virginia. The greatest percentage of these sites occur in association with third or lower order streams (Parker 1990:107-108). Slightly more than half of bifurcate components (n=637) in the Piedmont (54%), Ridge and Valley (67%), and Appalachian Plateau (55%) provinces of Pennsylvania are on floodplain related sites (Carr 1998b:85, Table 3). Wetlands and bay/basin features are a draw for large sites with bifurcate components on the Delmarva Peninsula and elsewhere in the Middle Atlantic region, as are floodplains of major drainages (Custer 1989:128-137). In the Coastal Plain of the region freshwater wetlands, swamps and bogs are the focus of Paleoindian through Middle Archaic settlements (Custer 1990:32). In general, Middle Archaic sites in the Middle Atlantic region are located in a wider variety of environmental settings and in different locations than those of earlier times with settings associated with wetlands remaining important (Custer 1996:153-154).

For the interior Coastal Plain of Virginia Mouer (1991:4-5) highlights spring heads on upper stream terraces, and gentle, south-facing slopes on lower terraces as primary locations of Archaic sites. Generalized landforms and stream associations are used in the analysis of the distribution of Late Archaic and Early Woodland sites by physiographic province in Virginia by Klein and Klatka (1991). There is an apparent trend toward a focus on floodplains and accompanied by a rise in the exploitation of upland habitats between the Middle and Late Archaic periods in all areas of Virginia. This trend continues into the Early Woodland period (Klein and Klatka 1991:165). In the Shenandoah Valley of Virginia major Early Woodland sites are located on river levees adjacent to the mouth of a tributary stream (Gardner 1986:68). In contrast, sites of the Middle Woodland period shift to the interior floodplain adjacent to poorly drained, flood chutes and backwater wetlands (Gardner 1986:73).

In the Ridge and Valley of Pennsylvania Late Archaic sites are located in a variety of settings including near spring heads and benches on mountain slopes (Raber et al 1998:126). In a review of the Late Archaic, Wall (2015:42) notes that sites with Lamoka components in the West Branch Valley of the Susquehanna River in Pennsylvania occur at or near the confluence of tributaries with the river. In the Lower Susquehanna sub-basin, including the Piedmont Lowlands and Piedmont Uplands, all Transitional sites are within 250 meters of a stream. In contrast, in the Central Susquehanna sub-basin, which includes the Appalachian Plateau and Ridge and Valley provinces, all Transitional sites are within 520 meters of surface water (Wholey 2015:115-116). In eastern Pennsylvania the location of Late Archaic, Transitional, and Early Woodland sites are similar (Carr 2015:71-72). Early and Middle Woodland components are the most poorly represented in Wyatt's (2002:Table 1) compilation of Late Archaic through Late Woodland data for the Susquehanna River basin in Pennsylvania. Compilations of environmental variables associated with sites of a particular cultural historical period must be done with respect to distinctive environmental zones or physiographic provinces, or informative variability will be masked as is evident in Table 7 above.

E. Subsequent Practices in the Delaware Valley and New Jersey

A systematic survey of portions of the Outer Coastal Plain and Pine Barrens in New Jersey served as the basis for the initial development of a statistically based predictive model developed as a result of a series of projects by Tony Ranere and Pat Hansell (Hansell and Ranere

1989, 2017; Ranere and Hansell 1984, 1985, 1987a, b). The model is based on data derived from survey transects 50 meters wide and totaling 100 kilometers length situated in the Pinelands of Atlantic and Cape May counties (Hansell and Ranere 1989:11). Transects were primarily oriented along powerline right-of-ways which arguably represent a random sample of environments (Hansell and Ranere 1989:6, 10; Ranere and Hansell 1984). A variety of geographic and environmental variables were recorded for 19 sites encountered during fieldwork and 19 randomly selected non-site locations (Hansell and Ranere 1989:14) and analyzed, separately and in combination, in a stepwise logistical regression program. Table 9 provides a summary of the variables employed.

Hansell and Ranere (1989:19, 25) recognize that owing to sample size their work primarily demonstrates the potential utility of using logistical regression in generating useful predictions about site and non-site locations. At the time of their 1989 report, the creation and testing of models employing logistical regression for site and non-site areas had been completed for large portions of coastal Delaware (i.e., Custer et al 1986; Eveleigh et al 1983; Wells 1981), work that Hansell and Ranere (1989:5) briefly acknowledge. This work also is not discussed in their review of the use of predictive modeling in archaeology (Hansell and Ranere 1989:Appendix K). Nonetheless, a number of significant observations resulted from the Pine Barrens research.

Nearest and 2nd nearest water sources are significantly closer to sites than to non-site locations. The distance of sites to nearest 1st order stream, nearest freshwater source, nearest permanent freshwater source type, nearest hydrological source type, nearest hydrological assemblage, and nearest hydrological assemblage type is statistically greater than chance. Areas over 100 meters from a water source have a very low probability of containing archaeological sites. Soil drainage variability is also much greater in the immediate vicinity (100 meters) of sites than in non-site locations. Proximity of sites to areas with multiple soil types, especially poorly drained soils, is an important variable for site prediction and could be considered as a proxy for habitat and resource diversity (Hansell and Ranere 1989:22-23; 2017). Nearest 4th or higher order stream distance is the only variable whose distribution is not significantly different from chance and this counterintuitive observation could be the result of small sample size (Hansell and Ranere 1989:22-23).

In making recommendations for future research Hansell and Ranere (1989:Appendix K) recognize that most predictive efforts collapse the temporal and functional variability of archaeological sites to produce a single model for all classes of sites for all time periods. This is something generally done out of necessity and owing to the lack of sufficient data and sample sizes. As others working in the broader region have noted, it is important to collect information on non-site localities that is comparable to what is recorded for site locations to make the development of models more reliable. Standardized site forms themselves need to require the input of much more environmental/geographic data than is currently required (Hansell and Ranere 1989:25, Appendix D, Part 1). Likewise, field methods employed during archaeological surveys need to be sufficient to reliably conclude that sites are not present in particular settings.

TABLE 9
Variables Employed in Pine Barrens Modeling Project, New Jersey*

Variable	Variable States
Nearest hydrological source type	river, stream, spring, pond, lake, bog, cranberry bog, swamp, embayed swamp, freshwater marsh, tidal marsh, back bay, open bay, semi-enclosed bay, inlet ocean, artesian well, intermittent stream
Nearest hydrological source distance**	Measurement in meters
Second nearest hydrological source type	river, stream, spring, pond, lake, bog, cranberry bog, swamp, embayed swamp, freshwater marsh, tidal marsh, back bay, open bay, semi-enclosed bay, inlet ocean, artesian well, intermittent stream
Second nearest hydrological source distance	Measurement in meters
Nearest hydrological assemblage type	stream-river confluence, stream-stream confluence, stream-lake confluence, stream-pond confluence, stream-estuary confluence, stream-wetland confluence
Nearest hydrological assemblage distance	Measurement in meters
Nearest permanent freshwater source type	river, stream, spring, pond, lake, bog, cranberry bog, swamp, embayed swamp, freshwater marsh, artesian well, other
Nearest permanent freshwater source distance	Measurement in meters
Nearest Hydrological Source Direction	North, east, south, west, northeast, southeast, northwest, southwest
Nearest 1st order stream distance	Measurement in meters
Nearest 2nd order stream distance	Measurement in meters
Nearest 3rd order stream distance	Measurement in meters
Nearest 4th or higher order stream distance	Measurement in meters
Landform(s) in parcel	knoll, hill, dune, oxbow, saddle, ridge, cuesta, point bar, alluvial fan, floodplain, river terrace, coastal terrace, peninsular terrace, escarpment, delta lobe, delta, island, lee barrier island, sea island barrier, lake peninsula, bay peninsula, barrier island, bay beach, barrier spit lake point, bay point, ocean point, levee, bay beach/delta, depression, flat, complex, other
Relic landform feature types in or near parcel	river meander scar, stream meander scar, oxbow, oxbow lake, pluvial lake, pingo or thermokarst, beach ridge, dune, none
Maximum elevation	Measurement in meters above sea level
Major soil type in parcel	Mapped soils series for relevant county
Minor soil type in parcel	Mapped soils series for relevant county
Soil type(s) contiguous to parcel	Mapped soils series for relevant county
Major soil drainage type	excessively drained, well drained, moderately well drained, somewhat poorly drained, poorly drained, very poorly drained
Minor soil drainage type	excessively drained, well drained, moderately well drained, somewhat poorly drained, poorly drained, very poorly drained
Contiguous soil drainage type	excessively drained, well drained, moderately well drained, somewhat poorly drained, poorly drained, very poorly drained
Vegetation type: Upland Forest Complex	pine-oak, oak-pine, non-pine barrens, cedar swamp, hardwood swamp, pitch pine, edge area, inland marsh, intertidal wetlands, other
Vegetation type: Lowland Forest Complex	cedar swamp, hardwood swamp, pitch pine, edge
Vegetation type: Non-Forest Areas	inland marshes, intertidal wetlands, edge, other
Lithic Source Type(s) in or Near Parcel	cryptocrystalline, quartzite, ironstone, gravel, outcrop, other
Lithic Source Type Size	pebble, cobble, boulder
Lithic Source Distance if not in Parcel	Measurement in meters

*Data derived from Hansell and Ranere 1989:Table 3, Appendix E. **distances to river/streams actually reflect distances to floodplains or mapped alluvial soils as the current position of streams may have changed over time (Hansell and Ranere 2017)

Using a random sample of 64 sites Walwer and Pagoulatos (1990) examined the relationship between a series of environmental variables associated with known sites in Ocean

County, New Jersey (Table 10), and the degree to which those same variables are associated with a random sample of 64 non-site or control points. The study area is situated in the Outer Coastal Plain. Single control points was selected from each of the 64 quadrats used as base map for the county soil survey. Considering that Ocean County is an area of 411,000 acres (Walwer and Pagoulatos 1990:77) each quadrat represents approximately 6422 acres. Environmental variables were assessed for a catchment with a radius of 2000 feet for each archaeological site and control point (Walwer and Pagoulatos 1990:79). Each control point and its catchment equates to approximately 4.5% of the area of a quadrat.

TABLE 10
Variables Used in Assessing Locations of Sites and Control Points Ocean County, New Jersey*

VARIABLE	VARIABLE STATE
Distance to surface water	measured to nearest 20' interval
Water type	fresh water, brackish water, salt water
Wetland rank	5 acres or less (low rank), greater than 5 acres (high rank)
Stream order	1st, 2nd, 3rd, etc.
Surface drainage	excessive, well drained, moderately well drained, poorly drained
Soil type	per county soil survey
Elevation	measured to nearest 5 foot interval
Slope	0-5%, 6-10%, greater than 10%
Aspect	north, northeast, northwest, south, southeast, southwest, east, west, level landform
Landform	terrace, floodplain, marsh, depressional area, divide, side slope, toe of slope
Habitat resource potential	grains, seeds and crops; hardwood trees; wetland plants; woodland wildlife; and wetland wildlife. Each ranked very poor, poor, fair, or good.
Distance to historic trail	measured to the nearest 1000 feet

*abstracted from Walwer and Pagoulatos 1990

The chi-square test was used to examine whether sites and control points exhibit similar associations with each of the environmental variables selected for evaluation. Statistically significant differences in the degree to which a given variable is associated with sites versus control points are highlighted, and implied to have predictive value in modeling. Strong correlations with site locations are noted for brackish water, high stream rank (2nd or higher order streams), low elevations, historic trails, terraces/low divides, and soil types representing nearly level, moderately well to excessively drained soils (Walwer and Pagoulatos 1990:81-82). Table 11 collates data regarding site locations and distances to surface water and stream order for comparison with similar data from other portions of the Middle Atlantic Region.

The results of the study are not compared with the results of the Hansell and Ranere (1989) study of Outer Coastal Plain areas, although there is a degree of overlap between the variables that each took into consideration. Conclusions regarding the distance of sites to nearest surface water are generally comparable. Soil type variability in proximity to sites was suggested by Hansell and Ranere (1989: 22-23; 2017) to represent a close association between sites and habitat/resource diversity. Using different measures for habitat resource potential, Walwer and Pagoulatos (1990:82) found no significant association with site locations. However, the significant association of sites with brackish water arguably represents a link with potentially highly productive areas (Walwer and Pagoulatos 1990:82).

TABLE 11
Relation of a Sample of Sites to Surface Water Ocean County, New Jersey*

OBSERVATIONS	DISTANCE TO NEAREST WATER (meters)	HIGHEST STREAM ORDER WITHIN CATCHMENT AREA (609 meter radius)	WATER TYPE
Sites in Analysis	64	62	64
Range	0 - 304.5	1st to 4th	fresh water, brackish water, salt water
Mean	40.8	2.1	na
Median	18.3	2nd	na
Trends	50% within 18.3 meters 75% within 42.7 meters 90% within 146.3 meters	Statistically significant association between 2nd or higher order stream	70.3% associated with brackish water 26.5% associated with fresh water 3.1% associated with salt water

*Data and additional calculations based on Walwer and Pagoulatos 1990:Table 1. Original distance measurements were in feet.

Relevant to middle sections of the Delaware Basin, models developed and tested for highway projects identify relatively level and well drained landforms within 150 meters of 3rd or higher order streams, and 100 meters from lower order streams as highly sensitive areas for the occurrence of sites (Diamanti 1995; Hay 1993). A 1999 review of CRM reports on file at the New Jersey Historic Preservation Office led Grossman-Bailey (2001:95) to conclude that settlement and locational models developed in the 1970s or early 1980s "were still very much in use". However, efforts at updating them with new data, or drawing on the efforts of researchers from other portions of the Middle Atlantic Region, could be noted. She implies that working within a CRM context constrains the degree to which models can be formulated and improved.

In a synthesis of New Jersey archaeology Mounier (2003:124-127) describes general characteristics associated with the location of sites such as well drained ground with sandy or loamy soils, and in proximity to sources of water. Some sites occupy hilltops with exceptional views. The largest and most complex sites occur in settings that offered diverse, abundant, and useful resources. Significantly, it is noted that the landscapes on which sites occur vary between physiographic provinces.

A 2005 highway-related project in Delaware employed a GIS approach in characterizing aspects of the environment in the development of a model whose purpose was to define areas of greater or lesser archaeological sensitivity, and not to predict the exact location of archaeological sites (Baublitz et al 2005). The project area falls primarily within the mid-peninsular drainage divide zone of the Upper Coastal Plain Physiographic Province characterized by low, rolling topography that forms the divide between streams tributary to the Delaware and Susquehanna rivers. Portions of the mid-drainage zone also are involved (Baublitz et al 2005:4)

The report includes a review and critique of previous and relatively recent modeling efforts relevant to the area. Curiously the early work of Wells (1981), Eveleigh et al (1983), Eveleigh (1984a, b), and Custer et al (1986) is not referenced although aspects of their innovative approaches were later adopted by researchers whose work is reviewed. As part of a critique of the inductive approach to modeling site sensitivity, the authors affirm the widely held observation that data available to researchers is often of variable reliability and reflects the biases inherent in the methods by which sites are identified and recorded (Baublitz et al 2005:39).

Importantly, the project-specific nature of inductive models also is emphasized (Baublitz et al 2005:39):

> Site predictive models depend on empirical discovery of statistically significant correlations and produce a series of generalizations that are valid only for the area from which the data are derived. Each study is independent, and the findings are not cumulative, in the sense that the results of one study cannot be used to refine the predictive model for future studies in other areas. This problem occurs because the approach provides no theoretical link between predictor variables or between those variables and human behavior.

The model developed by Baublitz et al (2005:47-65) blends aspects of inductive and deductive approaches. Select variables were used to characterize areas of high, moderate, and low potential for prehistoric and historic archaeological resources. The model distinguishes between the mid-peninsular drainage divide zone and the mid-drainage zone in assigning weighted values to the variables it considers.

The environmental variables initially considered by the model are assigned relative values reflective of their assumed significance. Six variables were defined to evaluate the prehistoric archaeological potential of the study area. Their significance is based on the current understanding of prehistoric land use and settlement systems, and the results of research associated with the U.S 13 Relief Route project. The variables include: (1) cost distance to streams; (2) cost distance to springs; (3) cost distance to stream confluences; (4) cost distance to wetlands; (5) percent slope; and (6) soil permeability. Historic and modern ground disturbances also are used to qualify the integrity of archaeological deposits that might exist in a given area (Baublitz et al 2005:48-49).

Recognizing that significant climatic and hydrological changes have occurred, the model assumes that the currently active and remnant stream channel patterning approximates conditions throughout prehistory (Baublitz et al 2005:47). It also is acknowledge that there may be relevant hydrological or topographic features that, because of their size, are not captured by available GIS mapping. Initial field reconnaissance was required to identify such areas and then used to revise assessments of archaeological potential (Baublitz et al 2005:73). Poorly drained soils (the Othello, Fallsington, and Johnston series) along drainage ways and around headwaters and upland swamps were employed in the identification of wetlands, as well in excluding landforms suitable for encampments (Baublitz et al 2005:48-49).

Different ranges or states of each of the six environmental variables were assigned. Goodness of Variance Fit was used to identify clustering within the range of scores that could potentially be generated. In this way the probability classes of high, moderate, and low were defined. With the probability classes identified, the Kvamme Gain statistic was used to test the model's efficacy using data from known sites, with revisions made as necessary to ensure that predictions resulted in scores better than chance (Baublitz et al 2005:48, 50, 52-53). The results are reflected in Tables 12 and 13.Weighted values linked with cost distances to streams and wetlands vary between the two environmental zones represented in the project area. A site's location on a micro-drainage divide also is valued only in the mid-peninsular drainage divide

TABLE 12
Variable Features, Ranges/States, and Weighted Values for the
Midpeninsular Drainage Divide, Coastal Delaware*

VARIABLE	VARIABLE STATE/RANGE	WEIGHTED VALUE
Cost distance to streams	0-150 meters	10
	150-250 meters	5
	250-500 meters	3
Cost distance to springs	0-100 meters	10
	100-200 meters	4
	200-500 meters	1
Cost distance to stream confluences	0-100 meters	10
	100-200 meters	4
	200-500 meters	1
Cost distance to wetlands	0-100 meters	10
	100-200 meters	4
	200-500 meters	1
Percent slope	0-3%	10
	3-8%	10
	greater than 8%	5
Soil permeability	rapid, moderately rapid, or moderate	10
	moderately slow	5
	slow	0
	very slow	0
Micro-drainage divide		20

*Abstracted from Baublitz et al 2005:Tables 2.

TABLE 13
Variable Features, Ranges/States, and Weighted Values for the
Mid Drainage Zone, Coastal Delaware*

VARIABLE	VARIABLE STATE/RANGE	WEIGHTED VALUE
Cost distance to streams	0-200 meters	10
	200-350 meters	5
	350-500 meters	3
Cost distance to springs	0-100 meters	10
	100-200 meters	5
	200-500 meters	2
Cost distance to stream confluences	0-100 meters	10
	100-200 meters	5
	200-500 meters	2
Cost distance to wetlands	0-200 meters	10
	200-350 meters	5
	350500 meters	3
Percent slope	0-3%	10
	3-8%	10
	greater than 8%	5
Soil permeability	rapid, moderately rapid, or moderate	10
	moderately slow	5
	slow	0
	very slow	0
Micro-drainage divide		NA

*Abstracted from Baublitz et al 2005:Tables 3.

zone. A series of maps display the distribution of variables and their combination into probability areas (Baublitz et al 2005:Figures 2-7). Not provided is the range of scores used to define high, moderate, and low probability areas.

Portions of the Lower and Middle Delaware Valley are included in the modeling of site locations in the Piedmont and Coastal Plain physiographic provinces of Pennsylvania (modeling regions 9 and 10) by Harris et al (2014c). Site locations also are modeled for the New England/Reading Prong, Ridge and Valley provinces, and part of the Appalachian Plateau Province which are relevant to the Upper Delaware Valley project area (see Table 4, this report). The approach taken for model formulation parallels that for other areas of Pennsylvania and discussed above (Harris et al 2014c:58).

Modeling for the very small Coastal Plain portion of Pennsylvania seems suspect for extrapolation to the much greater extent of this physiographic province in New Jersey. Harris et al (2014c:54-56) combined data from 360 sampled sites in the Piedmont and Coastal Plain portions of Pennsylvania in their analysis, further questioning the relevance of their effort to the Inner and Outer Coastal Plains of New Jersey. However, the methodological approach is worth emulating. Their model for combined regions 9 and 10 is more appropriate for the Piedmont areas of Pennsylvania and New Jersey. Modeling for the Ridge and Valley, New England, and Appalachian Plateaus (modeling Regions 7 and 8) also should be relevant to New Jersey and New York portions of the current study area.

Using data from 7,297 prehistoric archaeological components an ensemble model for the regions was created from 66 candidate models employing 93 individual environmental variables (Harris et al 2014c:89, Appendices C-E). This resulted in:

> a model of all four regions that correctly classifies 98.5% of known site-present cells within 26.8% of the study area, for a Kg of 0.726. In actuality, the model is capable of correctly predicting the location of all archaeological sites and minimizing the site-likely area to a much smaller percent of the study area, but the selection of a low-end threshold for the site-likely area was intentionally set to approximately 33% of the study area. Compared to a random survey, the chances of finding a site in the combined high and moderate sensitivity area are 3.651 times greater (Harris et al 2014c:89).

Figure 3 depicts sensitivity areas for all for regions of Pennsylvania. Intuitively one would expect clustering of high and moderate probability areas along the Delaware River comparable to the clustering of such areas in more western/interior zones. Figure 3 shows that this is not the case. Such clustering is somewhat visible in the Upper Delaware Valley and may reflect the intensive surveys of floodplains and terraces associated with the proposed Tocks Island Dam and the development of the Delaware Water Gap National Recreation and Upper Delaware Scenic and Recreational River areas. As emphasized repeatedly by Harris and colleagues, their modeling efforts relied heavily on data associated with known site locations which may have skewed results.

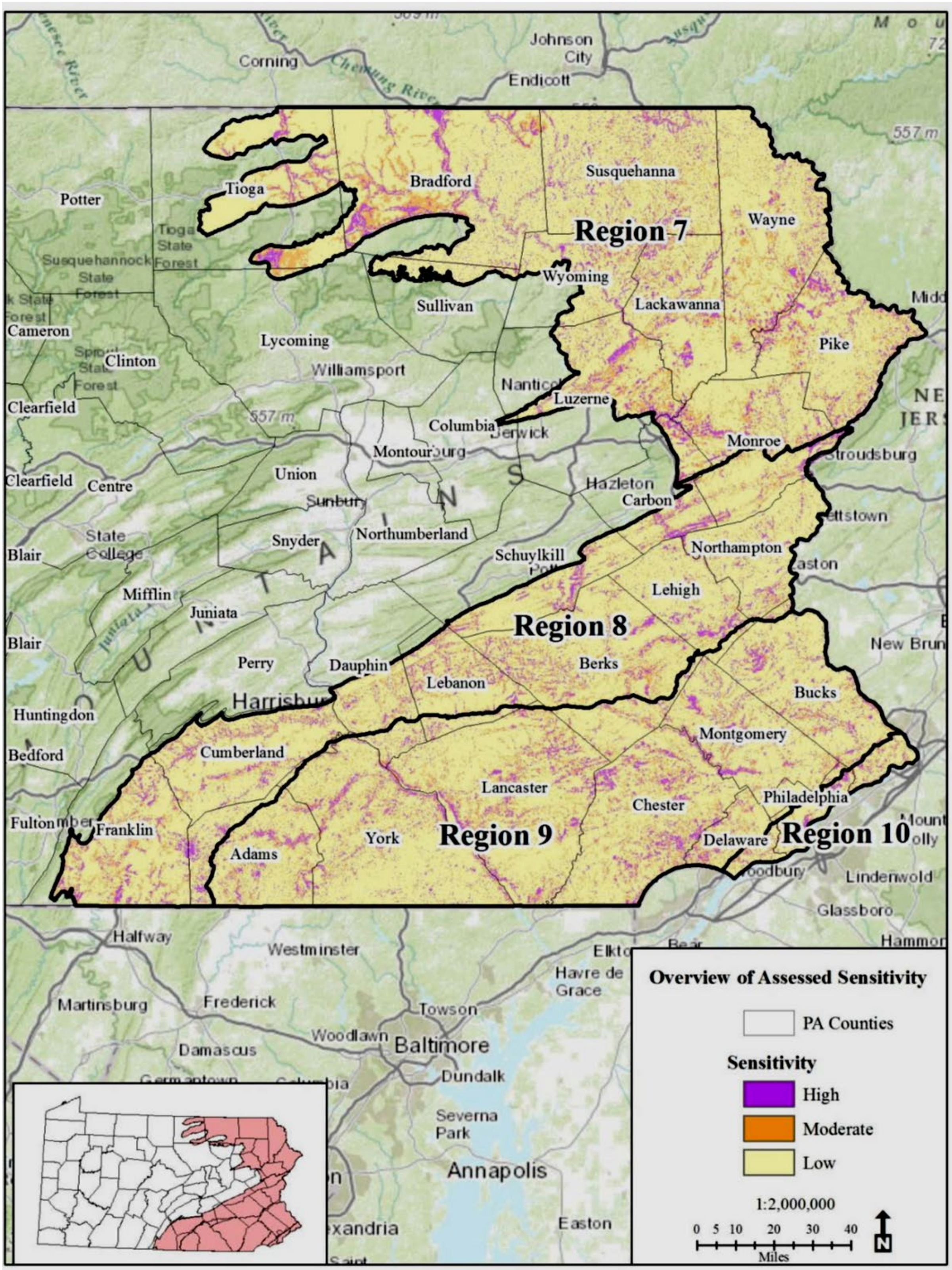

FIGURE 3. Overview of Assessed Site Sensitivity for Modeling Regions 7-10 in Pennsylvania. Source: Harris et al 2014c:Figure 29.

In a summary review of CRM investigations in New Jersey McHugh (2015) notes that models tend to stipulate that sites occur within 300 feet of a water source or stream. This generally coincides with the results of New Jersey studies previously discussed. However, he observes that there are many known sites in the Coastal Plain that break this rule without presenting qualifying data (but see discussion of Grossman-Bailey 2001 below). Published environmental data (e.g., soils, wetlands, pre-development topography) are not always accurate owing to the scales at which observations and mapping take place, potentially confounding modeling. McHugh concludes that existing models seem more relevant to later Woodland sites given the relatively "modern" nature of the environmental data used in models.

Modeling or the delineation of predictive variables specific to cultural historic periods rarely rises to the level of detail as ahistorical models. Based on the Pennsylvania Archaeological Site Survey files, the majority of Paleoindian sites (97%) in the Delaware basin are located along the terraces of the Delaware, Lehigh, or Schuylkill rivers, in the vicinity of the jasper quarries, or adjacent to natural lakes in the Poconos (Carr and Adovasio, in press). Paleoindian site densities are particularly high in the Lehigh sub-basin (Carr and Adovasio, in press).

Pagoulatos (1992, 1998, 2000, 2001, 2002a, 2002b, 2003, 2004, 2006, 2007) produced a series of settlement pattern studies for New Jersey covering the Paleoindian through Contact periods. The primary purpose of these works is a synthesis of settlement patterns based on a quantitative approach to characterizing artifact assemblages of specific cultural historical periods by occupation types and activity diversity. Each work contains general statements about the settings of sites by physiographic province that are useful but somewhat difficult to operationalize in a predictive model, as is the case with other syntheses of cultural history.

For the Delaware Valley as a whole Kraft (2001:76-77) notes that Paleoindian sites are located on well drained ground near streams that provide surface water and the possibility of canoe transportation. Elevated settings providing vantage points from which to observe the movements of herd animals may also be loci of archeological deposits. In the Coastal Plain peri-glacial features or pingos are a distinctive setting associated with Paleoindian sites (Kraft 2001:76-77). The focus on peri-glacial features by early native peoples was noted in earlier studies and continues to be evident in the ongoing analysis of Paleoindian to Middle Archaic site settings (e.g., Grossman-Bailey 2001:101, Table 7.10; Pagoulatos 2000:Table 1; 2002b:Table 1, Figure 3; 2003:Table 1; 2004:Table 1, Figure 5). This observation appears to be most relevant to the Inner Coastal Plain (Grossman-Bailey 2001:153-154).

Landscapes adjacent to major drainages, glacial features and related marsh environments, and the remnants of glacial lakes are settings frequently associated with Paleoindian sites in New Jersey, although terrace settings account for the majority (Pagoulatos 2004:Tables 1, 2, Figure 5, 135-137). A recent evaluation of the setting of Paleoindian sites in New Jersey indicates that 73% of sites are situated on stream terraces, followed by floodplains at 8.7%. Sites associated with peri-glacial features (4.8%), the shore (5.6%), and the Cuesta mount (1.6%) reflect additional settings for New Jersey's Coastal Plain (Lattanzi 2017:56, Figure 7).

Early Archaic sites in New Jersey predominantly are associated with terrace/floodplain landscapes. In a comparison of Kirk and bifurcate-related components, the former are nearly exclusively associated with terrace/floodplain settings while the later, also found to a high degree on such landscapes, are as frequently found in other settings (Pagoulatos 2003:Figures 10, 11). As with Paleoindian components, those of the Early Archaic are predominantly (73%) associated with major drainages (Pagoulatos 2003:33), a trend that continues into the Middle Archaic period (Pagoulatos 2002b:Figure 4). In the Outer Coastal Plain of New Jersey major Middle Archaic through Late Woodland sites occur along the main trunk of high order streams, and particularly at the confluences of such streams (Grossman-Bailey 2001:107-108 summarizing the research of R. Alan Mounier).

Settings of Late Archaic base camps in the Piedmont Uplands of the Delaware drainage are found in a variety of settings including associations with sinkholes, ponds, and small freshwater wetlands (Custer 1996:207). Late Archaic sites are frequently situated in drainage divides between the streams of the Delaware and Susquehanna basins. Stream headwaters in the Piedmont Uplands are often associated with poorly drained soils reflecting current or former wetlands. Elevated knolls or ridges associated with these areas often contain abundant Late Archaic artifacts. (Custer 1996:208). The use of massive outcrops of argillite found in the Piedmont, and primary sources of jasper situated in the Reading Prong intensifies during the Late Archaic relative to earlier times (Custer 1996:203-204, 211-212). Kraft asserts that principle Late Archaic settlements in the Delaware Valley are located along major streams rivers that afforded easy dugout canoe transportation. He also acknowledges the important association of sites with drainage divides, swamps, springs, ridgetops and overlooks, kame terraces, and the edges of outwash plains (Kraft 2001:111).

Procurement sites of the Minguannan Complex of the Late Woodland period are found in the Piedmont Uplands on the edges of rolling knolls adjacent to ephemeral streams (Custer 1996:287-288). Base camps are found in the most productive settings such as the floodplains of major streams and areas adjacent to wetlands (Custer 1996:288).

Well drained, low relief landscapes in proximity to the following types of stream environments are associated with Late Woodland sites in the Inner Coastal Plain to Piedmont transition (Custer 1996:289-290; Stewart et al 1986:70):

- river and marsh associations; marshes associated with streams of any order;
- confluence of the river and tributary streams of any order;
- junction of streams of any order;
- junctions of second or higher order streams with extinct or seasonal drainages; and
- drainage headwaters, including springs.

A focus of Grossman-Bailey's synthesis of Outer Coastal Plain archaeology in New Jersey is the quantification of site locations (Grossman-Bailey 2001:110). The study was the first macro-scale analysis of prehistoric settlement patterns and site distributions in relation to environmental factors for the Outer Coastal Plain, and included the examination of 1128 sites (Grossman-Bailey 2001:127).

Table 14 summarizes data regarding the association of sites with water in the Outer Coastal Plain. The overwhelming majority of sites are within 1000 feet (304.8 meters) of water.

TABLE 14
Proximity of Sites to Water in the Outer Coastal Plain of New Jersey*

Parameter	Number of Sites	Percent of Total Sites
All sites within 1000 feet (304.8 m) of water	955	84.6 (n=1128)
All sites within 1000 feet (304.8 m) of 4th or higher order stream	268	23.7 (n=1128)
All sites within 300 feet (91.4 m) of water	382	33.8 (n=1128)
All sites within 300 feet (91.4 m) of 4th or higher order stream	78	6.9 (n=1128)
Paleoindian sites within 1000 feet (304.8 m) of water	13	86.6 (n=15)
Paleoindian sites within 1000 feet (304.8 m) of 4th or higher order stream	5	33.3 (n=15)
Paleoindian sites within 300 feet (91.4 m) of water	4	26.6 (n=15)
Paleoindian sites within 300 feet (91.4 m) of 4th or higher order stream	0	0
Early Archaic sites within 1000 feet (304.8 m) of water	16	88.8 (n=18)
Early Archaic sites within 1000 feet (304.8 m) of 4th or higher order stream	4	22.2 (n=18)
Early Archaic sites within 300 feet (91.4 m) of water	6	33.3 (n=18)
Early Archaic sites within 300 feet (91.4 m) of 4th or higher order stream	1	5.5 (n=18)
Middle Archaic sites within 1000 feet (304.8 m) of water	33	76.7 (n=43)
Middle Archaic sites within 1000 feet (304.8 m) of 4th or higher order stream	19	44.1 (n=43)
Middle Archaic sites within 300 feet (91.4 m) of water	10	23.2 (n=43)
Middle Archaic sites within 300 feet (91.4 m) of 4th or higher order stream	4	9.3 (n=43)
Late Archaic sites within 1000 feet (304.8 m) of water	130	82.8 (n=157)
Late Archaic sites within 1000 feet (304.8 m) of 4th or higher order stream	29	18.4 (n=157)
Late Archaic sites within 300 feet (91.4 m) of water	47	29.9 (n=157)
Late Archaic sites within 300 feet (91.4 m) of 4th or higher order stream	8	5.0 (n=157)
Early Woodland sites within 1000 feet(304.8 m) of water	123	84.2 (n=146)
Early Woodland sites within 1000 feet (304.8 m) of 4th or higher order stream	26	17.8 (n=146)
Early Woodland sites within 300 feet (91.4 m) of water	55	37.6 (n=146)
Early Woodland sites within 300 feet (91.4 m) of 4th or higher order stream	10	6.8 (146)
Middle Woodland sites within 1000 feet (304.8 m) of water	113	84.9 (n=133)
Middle Woodland sites within 1000 feet (304.8 m) of 4th or higher order stream	22	16.5 (n=133)
Middle Woodland sites within 300 feet (91.4 m) of water	47	35.3 (n=133)
Middle Woodland sites within 300 feet (91.4 m) of 4th or higher order stream	6	4.5 (n=133)
Late Woodland sites within 1000 feet (304.8 m) of water	217	90.0 (n=241)
Late Woodland sites within 1000 feet (304.8 m) of 4th or higher order stream	52	21.5 (n=241)
Late Woodland sites within 300 feet (91.4 m) of water	90	37.3 (n=241)
Late Woodland sites within 300 feet (91.4 m) of 4th or higher order stream	11	4.5 (n=241)

*Data derived from Grossman-Bailey (2001:Tables 7.4, 7.7,138-139). Original distance measurements in feet.

This trend changes very little through time with Late Woodland sites showing the most distinctive percentage (90%) of sites found within 1000 feet of a water source (Grossman-Bailey 2001:142-143, Table 7.7). Middle Archaic sites stand out regarding the relationship of sites within 1000 feet of a 4th or higher order stream.

Sites within 300 feet (91.4 meters) of a water source account for only 33.8% of all sites. In contrast, the analysis of a sample of Outer Coastal Plain sites by Walwer and Pagoulatos (1990) indicates that 75% of sites are within 42.7 meters of water (see Table 11, this report). Grossman-Bailey's analysis is based upon a much larger and comprehensive sample of sites which partially may explain the discrepancy between the studies. The strictly random selection of sites in the Walwer and Pagoulatos analysis also may have impacted results. Running additional random iterations of the Ocean County data might be revealing. Soil drainage and soil fertility or productivity are ambiguous in terms of their predictive value in Grossman-Bailey's analysis (2001:147, 150-151).

Landscape settings were recorded for 931 of 1183 sites and for 1168 chronological components (Grossman-Bailey 2001:151, Table 7.10). Settings observed include: river or stream terraces; coastal terraces; pingos/periglacial features or ponds; stream confluences; freshwater marshes; saltwater marshes; and hills, knolls, dunes or ridges. Irrespective of cultural historical component, stream terraces account for the greatest percentage of sites 45.5%. Hills, knolls, dunes or ridges account are a distant second at 16.7% with the remaining settings at lower percentages (Grossman-Bailey 2001:151-152). Cultural components reveal a more distinctive pattern in associations with stream terraces. Paleoindian (70.5%) and Early Archaic (70%) components have a greater affiliation with stream terraces than those of other time periods, which range between 37.3-46.8%. These calculations are based on data provided in Grossman-Bailey's Table 7.10.

Using GIS technology Marcopul (2007) examined the relationship between the distribution of archaeological sites in the Crosswicks Creek Watershed (New Jersey Coastal Plain) and environmental variables as a basis for determining the contemporaneity of site occupations, population densities, resource use, and group movements. The analysis included 86 sites representing the Late Archaic through Late Woodland periods. Variables frequently associated with site locations are not highlighted in the work. However, in the process of determining resource availability within the study area a series of equations based upon environmental characteristics are developed following the work of Binford (2001). In summary, the equations model the amount of plant and animal food available, the number of people that a particular environment (per 100 km^2 unit) could support based on a dependency on plant foods, animal foods, or combinations of both (Marcopul 2007:189-197). The potential input of aquatic resources was considered in a more qualitative manner (Marcopul 2007:201-207). This approach would be useful in the future construction of models that assess the potential productivity of survey areas prior to predicting site locations.

Following the work of Boyd (2005) and others Marcopul (2007:218-224) examined the location of sites in relation to historically documented Indian trails. Visual inspection of mapped sites and trails revealed a close correspondence. It is interesting that the results of a least cost path simulation differ significantly from the route of a major historic Indian trail through her study area (Marcopul 2007:230, 251).

A mitigation project in the Middle Delaware Valley provided an opportunity to model settlement and subsistence patterns for Hunterdon and Mercer Counties in New Jersey, and portions of Berks, Bucks, Lehigh, Montgomery, and Northampton Counties in Pennsylvania (Albright 2014; Mikolic and Albright 2012:7-1 to 7-38). This included portions of the Coastal Plain and Piedmont physiographic provinces. The distribution of Late Archaic, Early/Middle Woodland, and Late Woodland site types was modeled in relation to the preferred habitats of subsistence resources. A GIS analysis of elevation, slope, aspect, topographic position, soil drainage, the presence-absence of hydric soils, seasonally preferred habitats of mast and useful plant species, and seasonal bear and deer habitats served as the backdrop for examining the distribution of sites. Maps were generated by season depicting gradations from a high coincidence of preferred resource habitats to a low coincidence of preferred resource habitats.

The Late Woodland analysis was the most compelling and reflected a common patterning for the overall Woodland period. Two distinct settlement/subsistence patterns are proposed. One is focused on the floodplain of the Delaware River and adjoining areas with the second focused on interior high order stream. Macro-band base camps are located in areas with greater than average coincidence of resources for 3 or more seasons of the year. In addition, they are situated within one kilometer of a wide range of plant resources. Micro-band camps are all associated with riparian settings and/or freshwater wetlands, and winter to spring yarding areas of deer. Procurement sites tend to cluster near macro-band basecamps and are associated with a range of plant resources, physiographic settings, and faunal resources. The patterning of Late Archaic sites stands in contrast with most sites identified as camps located along interior drainages.

F. Summary of Subsequent Practices

A wide variety of models and approaches continue to be employed in archaeological surveys throughout the Middle Atlantic Region and in the Delaware Valley, with the majority being atemporal. There are, however, clear differences in settlement patterns, the use of specific types of landscapes, and the importance of specific environmental variables through time that can be noted. The statewide models crafted by Harris and colleagues for Pennsylvania purport to capture the majority of sites, regardless of their cultural historical affiliation.

There is an increase in the use of GIS in the modeling process and in conjunction with digital sources of information has improved the ways in which environmental data are captured and utilized. The range of environmental data employed in a given model remains highly variable. In general, statistically- and GIS-based models make the most extensive use of basic environmental data. The comparison of environmental variables associated with site locations with the environmental background of random locations in a project area is emphasized to a greater degree than ever before in assessing the predictive value of specific variables, although it is a protocol that still remains to be widely adopted. Cost distances measured from sites to environmental settings also figure into more models than before. The resource potential of environmental areas, rather than the environmental associations of a specific location, also are used to designate archaeologically sensitive areas.

Employing cultural factors other than those closely related to economic behaviors remains problematic in model formulation, as acknowledged by most researchers. All models struggle with including specialized types of sites in the designation of archaeologically sensitive areas. Such sites include rockshelters, cemeteries and mortuary features in general. Field methods are adapted in many cases in attempts to locate rockshelters. This is important for many reasons not the least being that shelters can contain human remains. Pagoulatos' (2002a:34) statement that Early Woodland cremation loci are found on well drained terraces or promontories throughout New Jersey is one of the few recent attempts to synthesize locational data for mortuary sites.

Significantly, there is more widespread agreement that any model must be area specific; no one model, or the predictive value assigned to a specific variable, is applicable across all types of environmental zones. There is also widespread agreement that any model for any area needs to be constantly revised. This relates to the critical reliance each has on the environmental associations of known sites, the degree to which the landscapes of a given area have been sampled through archaeological survey, and the representative nature of recorded sites.

G. Guidance of State Historic Preservation Offices

Today, State Historic Preservation Offices provide varying degrees of guidance regarding archaeological surveys. No specific guidance on the use of predictive models in archaeological surveys in Virginia is provided by documents prepared by the Virginia Department of Historic Resources (VADHR 2016, 2017). The use of models is implicit in the language used in describing the development of research designs and research methodology: "research is conducted to build upon and often verify the known body of information" (VADHR 2017:15); "review of local and state planning documents will assist in developing survey strategies" (VADHR 2017:17); Phase I survey "is a broad visual inspection of cursory examination of historic resources in a certain geographic area and is particularly useful in determining or predicting the distribution of landscape resources in a certain geographic area VADHR 2017:62). In that federal projects require consideration of the Secretary of the Interior's Standards and Guidelines for Archaeology, predictive modeling and sampling may come into play:

> Predictive modeling can be an effective tool during the early stages of planning an undertaking, for targeting field survey and for other management purposes. However, the accuracy of the model must be verified; predictions should be confirmed through field testing and the model redesigned and retested if necessary (United States Department of Interior, National Park Service 1983 - 48 FR 44722).

Guidance for archaeological surveys in Maryland (Shaffer and Cole 1994) parallels the situation in Virginia with the use of predictive models not explicitly addressed. Sampling and a requirement that reports describe the relationship of the archaeological potential of an area, available data on site density, and field techniques employed, implies the use of predictive models (Shaffer and Cole 1994:7, 58). Federal projects initiated in the state would be impacted by the Secretary of the Interior's Standards and Guidelines for Archaeology, as they would be in Delaware, Pennsylvania, New York and New Jersey.

Delaware State Historic Preservation Office guidelines (DSHPO 2015) reference the use of sampling, predictive models, and justification of the approach and techniques employed in surveys. Reconnaissance level surveys are to be designed to provide a statistically representative sample of a project area (DSHPO 2015:9-10, 23-24). Significantly, a survey report must address how results confirm, reject, or require revisions to any predictive model employed (DSHPO 2015:24). No mention is made of the sensitivity maps and predictive variables resulting from the previous research of Custer and colleagues that exist for large portions of the state (e.g., Custer 1983a, 1986a; Custer and DeSantis 1986; Custer et al 1984, 1986; Eveleigh et al 1983), nor the more recent work of Baublitz et al (2005), although one might assume that these would be examined as part of any project's background research.

Pennsylvania's guidance regarding the use of predictive models in archaeological survey is well defined and the most detailed for the Middle Atlantic Region. A Statewide Pre-Contact

Probability Model was developed through the cooperative effort of the Pennsylvania State Historic Preservation Office (PA SHPO) and the Pennsylvania Department of Transportation (Harris et al 2015; PA SHPO 2017). Aspects of this project were summarized previously. The use of the model is required for areas of potential effect (APE) greater than 50 acres, or linear survey areas longer than 15 miles (PA SHPO 2017:21-22).

Survey results must be compared with the predictions of the statewide model addressing the following questions:

1) For each portion of your project area that has a displayed probability, do the results of archaeological testing support the model prediction?
2) If the results of survey differ from the model prediction, why do you think that is the case? (PA SHPO 2017:23).

The methodologies employed during the survey are used, in part, in the evaluation of the statewide model. Reports must include the completion of a testing methodology matrix (Table 15) and a narrative that provides:

1) A discussion of the approved testing methodology;
2) A discussion of how that methodology varied (if applicable) from the methodology used for the remainder of the survey;
3) A comparison of all testing results to the model prediction. Did the model work for predicting the locations of sites within the surveyed area? and
4) An analysis of the potential strengths and/or weaknesses in the model for future refinement (PA SHPO 2017:23-24).

TABLE 15
Testing Methodology Matrix for Use in Archaeological Surveys Completed in Pennsylvania*

Sensitivity Tier	Area Within Tier (square meters)	Percent of Total Project Area	Method(s) Used to Test Tier. Include % if multiple methods used	Number of Sites Located
High	sq. m.	%		
Moderate	sq. m.	%		
Low	sq. m.	%		

*Source: PA SHPO 2017:23

New Jersey guidelines for Phase I surveys (New Jersey Department of Environmental Protection, Historic Preservation Office 2018) include frequent mentions of the varying potential for archaeological sites to occur in an area leading up to discussions of how models should be formulated. Background research for a project should be sufficient to develop a site location model for a given project area given the understanding that its level of detail is dependent on existing data and its interpretation, and the expertise that investigators bring to the modeling process. Model variables may be drawn from aspects of an area's geology, pedology, geomorphology, and history of land use and disturbance. The types of sites that might be encountered, and methods appropriate for their discovery should be addressed. It is anticipated that the predicted value of a given location, area, or landform will be ordinal in scale (e.g., high, medium, low). The development of models that are time transgressive or period specific is seen as a long term goal for researchers in the state. Field results should be used to evaluate the predictive model used in any survey.

New York standards (New York Archaeological Council-NYAC 1994) recommend that during the pre-field gathering of background information for a project a consideration of relevant geomorphology, soils, culture history, and previous archaeological research be used to develop "explicit expectations or predictions regarding the nature and locations of sites" (NYAC 1994:1). In general, expectations for archaeological resources are based upon:

> …statements of locational preferences or tendencies for particular settlement systems, characteristics of the local environment which provide essential or desirable resources (e.g. proximity to perennial water sources, well drained soils, floral and faunal resources, raw materials, and/or trade and transportation routes), the density of known archaeological and historical resources within the general area, and the extent of known disturbances which can potentially affect the integrity of sites and the recovery of material from them (NYAC 1994:2).

The sensitivity/predictive model is subsequently used to design appropriate field procedures for the examination of an area. Reporting standards (NYAC 1994:3) do not explicitly call for an evaluation of the model based upon the results of fieldwork. Updated reporting requirements (New York State Historic Preservation Office 2005:2-3) include a discussion of "sensitivity assessment" and how expectations were developed; post-field evaluations of the sensitivity model are not mentioned.

Given SHPO guidance in the Middle Atlantic Region variation in model use will continue into the future. The exception will be Pennsylvania where all but the smallest projects will be testing and suggesting revisions to existing statewide models.

III. MODELING IN THE UPPER DELAWARE VALLEY

A. Ahistorical Models

In a previous section I commented on the 1913 compilations by Alanson Skinner and Max Schrabisch of the variables associated with Native American archaeological sites in New Jersey. In a number of publications Schrabisch provides synthetic comments for sites in northern New Jersey and the current project area, specifically focusing on rockshelters. Nearby running water is viewed by Schrabisch (1913a:39-40) as the primary factor governing the use of a rockshelter. Large shelters "facing southward and affording ample protection against the elements" were ignored "for no other reason than that water was too far away". Southern exposures are nonetheless included in a combination of predictive elements (Schrabisch 1919:148). Proximity to a natural travel route is also considered to be a factor determining whether or not a shelter gets used (Schrabisch 1917:31). Shelters in proximity to camps or villages also exhibit a greater variety of artifacts, and by inference activities, than those found elsewhere (Schrabisch 1917:32). Rockshelter use is postulated to be more frequent in the uplands of the Highland physiographic zone than in the Kittatinny, Watchung, Jenny Jump, and Musconetcong mountains (Schrabisch 1919:140). These observations are examined further later in this report.

Qualitative inductive models using select variables remain the norm in CRM surveys through the 1980s and later in the Upper Delaware, often drawing on studies from throughout the Middle Atlantic region and a variety of physiographic provinces (e.g., Stewart and Wuebber 1987). As is the case in the greater Delaware Valley and broader region, there are notable examples involving innovative ways of assessing the resource potential of landscapes in conjunction with a variety of statistical approaches to determining the archaeological sensitivity of project areas. The work of Harris and colleagues (Harris et al 2014c), previously discussed, is the most recent effort in this regard. Modeling efforts that have involved the Upper Delaware Valley and adjacent areas are summarized in detail below. Examples of overarching, inductive and ahistorical approaches are presented first and generally organized historically. Observations culled from the regional literature regarding the utility of specific variables, and those related to specific cultural historical periods follow after.

A relatively early and sophisticated approach was employed by Bailey and Dekin (1980) in an initial study of cultural resources in the Upper Delaware National Scenic and Recreational River of Pennsylvania and New York. The Upper Delaware National Scenic and Recreational River roughly extends from Hancock, New York in the north to Matamoras/Port Jervis downriver. A site location model initially developed in areas of central and southcentral New York was tested with data from the Upper Delaware including site locations derived from survey, background research and informant interviews. Harris (2013a:30-34) provides a critical review of the 1980 model in the course of developing statewide predictive models for Pennsylvania.

The model is based on scoring landscape suitability and diversity presuming a relationship with the economic interests of Native Americans. Scullane (1983:287-288) describes the model in a fuller reporting of the Bailey and Dekin project (Dekin et al 1983), with roots in research performed through SUNY-Binghamton dating to 1979:

> Basically, this model depicts the physiography of the region as a continuous desirability surface, whose peaks indicate locales of maximum physiographic variability. Desirability is a concept which combines observations on several variables to determine composite values. Site locations are expected in those areas which score highly, indicating access to a variety of microhabitats.

The Callicoon and Damascus 7.5' USGS quadrangles were chosen for the initial test of the applicability of the New York model to the Upper Delaware. This choice reflected the quantity of available data for both upland and lowland settings. Relevant portions of the two quadrangles were divided into 24 hexagonal units, each side measuring1 km, and each consisting of 214 acres (Bailey and 1980; Harris 2013a:31; Scullane 1983:293). Hexagonal units were chosen because of their ability to be packed and their close mathematical approximation to a circle.

The environmental quality of each hex unit was scored using 10 variables, with different variable states ranked. Cumulative variable scores characterized the suitability of a hex unit for the occurrence of archaeological sites (Harris 2013a:31-32; Scullane 1983:290-291). Cumulative scores included points for "proximity effects" reflecting the occurrence of variables in nearby portions of adjacent hexagonal units (Scullane 1983:290). The basic variables involved in the process (Harris 2013a:Table 4; Scullane 1983:290) include: highest stream rank/order; highest stream rank/order confluence, or confluence with other water body; slope, percent of terrain with slope of 5% or less; floodplain areas; and physiographic features including bogs, lakes, kames, valley trains, alluvial fans, and islands. The weights or values of variable states are shown in Table 16.

In applying a model developed elsewhere to the Upper Delaware, the modelers acknowledged a number of potential limitations. Different variables may have significance in different geographic areas. Different types of drainage networks would influence how stream or confluence variable states are scored. All of these factors would impact the range of scores attributed to areas with high, medium, and low sensitivities for the occurrence of archaeological sites. Any variables need to be observable at the mapped scale of analysis, in this case 7.5' USGS quadrangles.

A total of 83 sites were used in the testing of the model with modalities in the frequency distribution of sites by hexagon score used to suggest intervals of site sensitivity (Scullane 1983:293-295). Scores ≥13 are associated with a very high potential or rank for the occurrence of sites, scores of 10-12 with high sensitivity, 6-9 with medium sensitivity, and scores of 1-5 with low sensitivity (Scullane 1983:293). As seen in Table 17, highly scored, hexagonal units contain a disproportionate number of sites given the relatively low number of such units in the project area (Scullane 1983:296). The model performed successfully. Harris (2013a:32-33, Table 6) used these data to calculate the Kvamme Gain value for the four sensitivity classes of the Bailey and Dekin model (Table 18). The highest sensitivity classes appeared to be effective. However, "the medium sensitivity class was actually less likely to contain sites than by chance alone" (Harris 2013a:33).

TABLE 16
Variable Weights in the Bailey and Dekin Predictive Model for the
Upper Delaware National Scenic And Recreational River*

VARIABLE	SCORING CRITERIA	SCORE
Highest stream rank/order in hex	no streams	0
	primary feeder stream	1
	after confluence of two 1rst order streams	2
	after confluence of two 2nd order streams	3
	Delaware River	6
Highest stream rank confluence or confluence with other water body	incoming stream	rank/order of that stream
Slope – Terrain with slope of 5% or less	0% of total hex area	0
	1-24% of hex area	1
	25-49% of hex area	2
	50-74% of hex area	3
	75-100% of hex area	4
Floodplain	none	0
	1-24% of hex area	1
	25-49% of hex area	2
	50-74% of hex area	3
	75-100% of hex area	4
Physiographic Features (bog, lake, kame, valley train, alluvial fan, island)	none	0
	diameter of 1-7mm on 7.5' USGS quad	1
	diameter of 8-15mm on 7.5' USGS quad	2
	diameter 16-24mm on 7.5' USGS quad	3
	diameter 24mm on 7.5' USGS quad	4

*Adapted from Harris (2013a:Table 4) and Scullane (1983:290).

TABLE 17
Site Sensitivity Rankings and Site Distributions for the
Callicoon and Damascus 7.5' USGS Quadrangles*

	Very High Rank	High Rank	Medium Rank	Low Rank
Percent of total hexes in rank	13%	15%	48%	25%
Percent of total sites in rank	61%	23%	16%	0%
Percent of hexes with one site	89%	31%	9%	0%
Percent of hexes with multiple sites	59%	22%	4%	0%

*Adapted from Scullane (1983:295).

TABLE 18
Kvamme Gain Values for Site Sensitivity Rankings in the Bailey and Dekin Model,
Upper Delaware National Scenic And Recreational River*

Site Sensitivity Ranking	Percent of Project Area	Percent of Associated Sites	Kvamme Gain
Very High	13%	61%	0.787
High	15%	23%	0.348
Medium	48%	16%	-2.000
Low	25%	0%	n/a

*Source: Harris 2013a:Table 6.

The tested model was subsequently used to score the suitability for localities along the entire length of the Upper Delaware National Scenic and Recreational River (Dekin et al 1983; Scullane 1983). In general, the northern half of the is viewed as more suitable for occupation than the half below Narrowsburg, NY, although exceptions can be noted (Scullane 1983:296-297). The boundary between these two generalized zones of suitability correlates with “the rapid and noticeable transition between the northern beech-birch-maple forest type and the southern white pine-hemlock-hardwood forest” (Scullane 1983:297).

In summary, the model identifies 214 acre areas within which sites are most likely to occur, not the specific location of sites. It assumes that sites are situated to take advantage of a variety of resources, therefore the potential of broad landscapes, not isolated locations, needs to be the focus of modeling efforts. In the future, this approach could be supplemented in a staged way with models that attempt to target more precise site locations. Once highly scored suitability areas have been identified, the latter type of model might prove to be more predictively powerful in narrowing down locations of archaeological sites than when used solely to assess the potential of a survey area. This follows from the observation that there are typically more settings that qualify as having the potential to contain sites than actually produce sites when surveyed.

Comparable observations are made by Curtin (1981:96) and were noted earlier in this report. In 1981 he successfully used the SUNY-Binghamton approach in an examination of upland areas in Schuyler County, New York, the drainage divide between the Finger Lakes and the Upper Susquehanna. He emphasizes that the initial emphasis must be on identifying large scale suitability areas prior to assessing the archaeological potential of smaller scale landscapes (Curtin 1981:96). He further suggests that the size of hexagonal units could be adapted to the nature of the broader environment and the scales at which variables considered to be important become visible (Curtin 1981:97). At the time that this research was being done 7.5’ USGS quadrangle maps and soil survey maps constrained the scale at which sufficient observations could be made. Today, with GIS applications and fine grained digital mapping of environmental variables, more flexibility in the size of hexagonal units employed in modeling is possible. The hierarchical, nested approach outlined above could be implemented even in CRM pipeline projects with linear and relatively narrow areas of potential effect. It would require, however, scoring hexagonal units that extend beyond narrowly defined projects areas.

A 1982 highway project on the southern end of the Upper Delaware project area in Northampton County, Pennsylvania involved the development and testing of a predictive model (Hatch et al 1982; Hoffman 1983). The importance of lithic resources was one of the variables highlighted along with surface water and soil type. Lithic resources were deemed especially important in that the highway alignment (Route 78) passed through an area known for its sources of jasper and related Native American quarries. Sites were predicted to occur: within three kilometers of a jasper source; within 500 meters of streams (1st through 4th order); and on, or immediately adjacent to soils with a minimum fertility index of 85 (Hoffman 1983:25). Segments of the highway alignment were rated, low, moderate, high, or excellent depending upon the occurrence and admixture of these criteria.

Survey results for five of the nine project segments rated for their archaeological potential fall within an acceptable range of prediction. Results for the remainder of the ranked segments failed to support the model (Hoffman 1983:25-26, Table 6). The best correlation of predictions and results is between jasper sources and sites, even though sites found in the alignment had substantial amounts of artifacts made with types of lithic materials other than jasper. Using soil fertility/productivity as a predictive variable proved to be ineffective.

Kuznar (1984a, b) surveyed a stratified random sample of the Shohola Creek watershed in Pike County, Pennsylvania to further an understanding of settlement patterns. First, eleven environmental strata were defined on the basis of stream characteristics, associated landscapes, and wetlands. Strata were then organized into units whose productive value was ranked using soil ratings for woodland, oak, wetland, and wildlife productivity. A random sample of units within individual strata was then drawn for archaeological survey. Subsequent analysis revealed a strong relationship between sites and alluvial soils. In addition, the more environmental strata that occur within a 1 km radius of a given location, the more likely a site would occur. This resembles locations in proximity to zones of maximum habitat overlap and environmental diversity that figure in the early models of Gardner (1978, 1987), the land suitability approach of the SUNY-Binghamton model, and others (e.g., Custer et al 1986; Eveleigh 1984b; Hasenstab 1983, 1984).

Funk (1993:65-81, 248-258) combines an analysis of major environmental zones with the variables associated with the setting of archaeological sites in the Upper Susquehanna Valley of New York. His overall project area primarily encompasses Broome, Chenango, Cortland, Delaware, Madison, Otsego, and Tioga counties. Broome, Chenango, Delaware and Otsego counties are in closest proximity to the basins of the east and west branches of the Delaware River, drain the Appalachian/Allegheny Plateau, and encompass the largest percentage of archaeological sites involved in the analysis (Funk 1993:43, Figure 1; Figure 2, this report). As seen in Table 19, the vast majority of sites are associated with the Valley Floors environmental zone, acknowledging however, the probable bias of the focus of amateur and professional explorations in the past. Nonetheless, the fact that Valley Floors comprise such a small portion of the study area indicates that the pattern of site distribution likely reflects reality.

TABLE 19
Distribution of Sites by Environmental Zone in the Upper Susquehanna Valley, New York*

Environmental Zone	Approximate Area (square miles)	Percent of Study Area	Number of sites	Percent of Total Sites
Valley Floors	340	7.6	397	92.3
Valley Walls	320	7.2	19	4.4
Uplands	3796	85.2	14	3.3
Totals	4456	100	430	100

*Abstracted from Funk 1993:Tables 21 and 22.

Specific settings within each of the major environmental zones of the Upper Susquehanna are detailed in Tables 20-22. Site settings within 100 meters of water are significantly represented as are floodplain terraces and outwash plains and terraces. While the total number of sites found in the Valley Walls environmental zone is small, occupations in rockshelters predominate. Landscapes situated around stream headwaters and associated wetlands are an important locus of sites in the Uplands environmental zone. A later study of the area between the West Branch of the Delaware River and the Susquehanna River found upland sites in settings corresponding with Funk's categories of landforms associated with bogs, swamps, ponds and stream headwaters, including saddles between knolls and ridges (Hohman and Versaggi 2003:109) .

TABLE 20
Site Settings on the Valley Floors of the Upper Susquehanna Valley, New York*

Environmental Setting	Surface Water Association	Number Of Sites	Percent of Total Sites on Valley Floors
floodplain terraces	0-100 meters from river	175	44.1
floodplain terraces	>100 meters from river	7	1.8
outwash plains and terraces	0-100 meters from river	87	21.9
outwash plains and terraces	>100 meters from river	31	7.8
kame terraces and deltas	0-100 meters from river	13	3.3
kame terraces and deltas	>100 meters from river	36	9.1
isolated knolls and ridges	0-100 meters from river	12	3.0
adjacent to lake	lake	15	3.8
outwash landform	swamp/bog	8	2.0
alluvial fan of tributary stream	>100 meters from river	7	1.8
floodplain	swamp/bog	4	1.0
lower bedrock slopes	none listed	2	0.5

*Abstracted and modified from Funk 1993:Table 24.

TABLE 21
Site Settings in the Valley Walls Environmental Zone, Upper Susquehanna Valley, New York*

Environmental Setting	Surface Water Association	Number Of Sites	Percent of Total Sites on Valley Walls
rockshelters between streams	stream	8	42.1
rockshelter	spring	1	5.3
small stream bank	stream	5	26.3
benches, ridges, etc. between streams	stream	5	26.3

*Abstracted and modified from Funk 1993:Table 24.

TABLE 22
Site Settings in the Uplands of the Upper Susquehanna Valley, New York*

Environmental Setting	Surface Water Association	Number Of Sites	Percent of Total Sites in Uplands
saddle or valley	stream headwater	8	57.1
landform at stream headwater	swamp/pond/bog	2	14.3
summit knoll or ridge	none listed	1	7.1
summit knoll or ridge	stream headwaters	1	7.1
saddle between knoll or ridge	no association	1	7.1
rockshelter on saddle between knoll or ridge	none listed	1	7.1

*Abstracted and modified from Funk 1993:Table 24.

A multi-year effort to generate a predictive model for prehistoric site locations in the Delaware Water Gap National Recreation Area is reported by Botwick and Wall (1992, 1994; Wall and Botwick 1992, 1995). The study involved the survey of two broad transects (Bushkill and Milford) that crosscut the river valley within park, emphasizing upland settings. The

Bushkill transect is roughly 9-14 km and 2.4 km wide, and the Milford transect roughly 5-6 km long and 2.7 km wide. A review of modeling efforts dealing with upland sites in the Middle Atlantic Region, and the settings of previously recorded sites in the park, resulted in the selection of variables to be employed in predicting where sites might occur in the transects, and the cultural historical components likely to be represented in specific settings (Botwick and Wall 1994:75-78; Wall and Botwick 1995:21-46, 49-55). Fieldwork was conducted in 1991 and 1992. Predicted settings for sites include (Botwick and Wall 1994:78; Wall and Botwick 1995:21-46, 49-55):

- headwater zones where level, well-drained areas provide ready access to small first order streams and springheads, bench sections between headwater forks, drainage divides/saddles;
- well drained areas adjacent to upland swamps or wetland basins, lakes and ponds;
- well drained areas in hollows entrances at, or near confluences;
- well drained areas along low order streams;
- well drained areas along high order streams;
- kames and kame terraces;
- mid-slope benches and foot slopes;
- ridgetops/overlooks; and
- slope areas with rockshelters.

Results of the surveys and a test of the initial model seem equivocal, although the investigators conclude that when sites were found they occurred in expected locations (Botwick and Wall 1994:79). Table 23 tabulates site occurrences with the general settings employed in the predictive model. Figure 4 provides a topographic frame of reference for these settings. The disparity between the settings of previously recorded sites and those discovered during the surveys likely reflects the bias of the activities of artifact collectors and amateur archaeologists and the focus of investigations related to the proposed Tocks Island Dam project (e.g., Kinsey 1972). However, the three data sets do indicate the importance of terrace settings. Some differences are apparent between the 1991 and 1992 surveys including the frequency with which sites are found in footslope areas and in association with low order streams. The surveys make clear that any landform not associated in some way with surface water has a low potential for archaeological deposits (Botwick and Wall 1994:84; Wall and Botwick 1995:235). What is not detailed is the percentage to which settings similar to those associated with archaeological sites are represented in the overall environment. This makes it difficult to fully understand the predictive power of the variables being considered.

Using site data from Monroe and Pike counties, Pennsylvania, and a sample of sites from Warren and Sussex counties, New Jersey, an attempt was made to identify correlations between landforms and occupations related to a particular cultural historical period (Wall and Botwick 1995:255-256). Chi-square tests revealed no significant associations. A significant trend exists between sites of any period and kame terraces (Wall and Botwick 1995:4-5, Table 2), as is evident in the data presented in Table 23.

TABLE 23
Settings of 1991-92 Delaware Water Gap National Recreation Area Transect Survey Sites and Other Sites in a Regional Sample*

Site Settings and Associations	Previously Recorded Sites Exclusive of River Floodplains	1991 Survey Sites Exclusive of River Floodplains	1992 Survey Sites Exclusive of River Floodplains
Headwater Zones	11 (5.9% of total)	0	0
Upland Swamps	14 (7.6% of total)	3 (21.4% of total)	4 (23.5% of total)
Ridgetops/Overlooks	1 (0.5% of total)	0	0
Lakes/Ponds	15 (8.1% of total)	0	2 (11.7% of total)
Low Order Streams	7 (3.8% of total)	3 (21.4% of total)	8 (47% of total)
High Order Streams	5 (2.7% of total)	0	0
Footslopes	0	1 (7.1% of total)	0
Mid-slope Benches	7 (3.8% of total)	0	1 (5.8% of total)
Hollows	1 (0.5% of total)	0	0
Saddles	1 (o.5% of total)	0	0
Kames/Kame Terraces	57 (30.9% of total)	7 (50% of total)	2 (11.7% of total)
Totals	184	14	17

*Adapted from Wall and Botwick 1995:Table 1

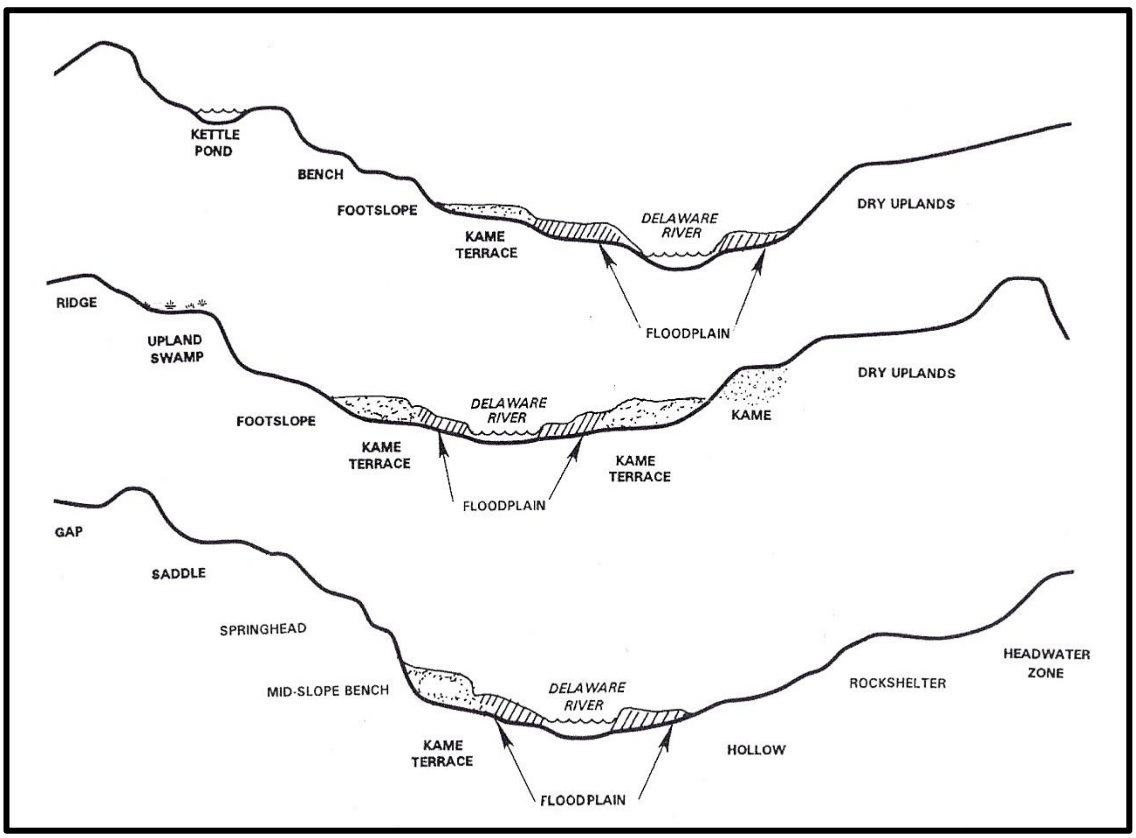

FIGURE 4. Topographic Cross-Sections of the Delaware Water Gap National Recreation Area, Pennsylvania and New Jersey. Source: Wall and Botwick (1995:Figure 3a).

Tables 24 and 25 use data compiled by Wall and Botwick (1995:Table 42) to examine the relationship between sites and surface water. In their compilation some distances are not given a precise value but recorded as <50 meters. In the developing the summary statistics shown in Tables 24 and 25 a measurement of 49 meters has been substituted for <50 meters. Data for distances to the nearest stream confluence was not always available which accounts for differences in the number of sites employed in a particular analysis. Further, the Pennsylvania sample consists of all known sites in Monroe and Pike counties as of 1993/1995, while the New Jersey sample is highly selective drawing on site files and reports that provided sufficient environmental data (Wall and Botwick 1995:235). This bias may account for differences between Pennsylvania and New Jersey site associations. However, it raises the question of the possible effect that different drainage nets and stream densities may have on the spatial relationship between surface water and archaeological deposits. Distances of up to100/150 meters account for a highest percentages of known site locations. Distances of sites to stream confluences does not seem to be a critical variable.

TABLE 24
Relation of Sites to Surface Water in a Sample From
Monroe and Pike Counties, Pennsylvania and Warren and Sussex Counties, New Jersey*

Areas in Analysis	**Distance to Nearest Water Range (sites in analysis)**	**Distance to Nearest Water Mean**	**Distance to Nearest Water Median**	**Distance to Nearest Stream Confluence Range (sites in analysis)**	**Distance to Nearest Stream Confluence Mean**	**Distance to Nearest Stream Confluence Median**
PA & NJ	0-480 meters (n=108)	68.3 meters	90 meters	0-3770 meters (n=95)	726.8 meters	670 meters
PA Only	0-480 meters (n=85)	75.8 meters	100 meters	0-3770 meters (n=84)	814 meters	670 meters
NJ Only	0-75 meters (n=23)	40.5 meters	30 meters	0-300 meters (n=11)	60.5 meters	39.5 meters

*Data employed in calculations derived from Wall and Botwick (1995:Table 42).

TABLE 25
Incremental Distances to Surface Water for a Sample of Sites From
Monroe and Pike Counties, Pennsylvania and Warren and Sussex Counties, New Jersey*

Sites In Analysis	**Sites 0-50 Meters to Nearest Water N/%**	**Sites 51-100 Meters to Nearest Water N/%**	**Sites 101-150 Meters to Nearest Water N/%**	**Sites 151-200 Meters to Nearest Water N/%**	**Sites 201-250 Meters to Nearest Water N/%**	**Sites 251-300 Meters to Nearest Water N/%**	**Sites >300 Meters to Nearest Water N/%**
PA & NJ (n=108)	63 58.3%	23 21.2%	12 11.1%	5 4.6%	1 0.9%	1 0.9%	3 2.7%
PA Only (n=85)	41 48.2%	22 25.8%	12 14.1%	5 5.8%	1 1.1%	1 1.1%	3 3.5%
NJ Only (n=23)	22 95.6%	1 4.3%	0	0	0	0	0

*Data employed in calculations derived from Wall and Botwick (1995:Table 42).

Bergman et al (1994/1996) developed a predictive model for use in a site survey of the Walpack Valley (Flat Brook drainage basin) within the Delaware Water Gap National Recreation Area building upon the work of Wall and Botwick. They employed five key variables: landform, percent slope, distance to nearest water, distance to nearest confluence, and elevation, with each variable examined as to its application to sites of a particular cultural historical period (Bergman et al 1996:66). The importance of landscapes in proximity to water is obvious in looking at existing site data for Pike, Monroe, Warren and Sussex counties as of the mid 1990s (Bergman et al 1996Table 4.1). However, these data may reflect the degree to which these topographic features comprise the makeup of areas that have been surveyed (Bergman et al 1996:68). Field testing involved the survey of a series of 39, 10 acre quadrats proportionately distributed across environmental strata: floodplain margins, terraces, lower slopes, upper slopes/ridgetops, high uplands, stream buffer. Few sites were found and important insights are incorporated into a subsequent project by Riegel et al (1994).

Riegel et al (1994:Tables 4-14) use an extensive list of sites from Northampton (n=39), Monroe (n=68), and Pike (n=146) counties, Pennsylvania, and Warren (n=43) and Sussex (n=88) counties, New Jersey to assess landscape and surface water associations in the further development of a predictive model for the Delaware Water Gap National Recreation Area. Landform, percent slope, distance to nearest water, distance to nearest stream confluence, and elevation are tracked for 384 sites representing 548 cultural period components (Riegel et al 1994:92-93). They incorporate data from the previous work of Wall and Botwick as well as the survey of the Walpack Valley by Bergman et al (1994/1996) and their analysis of existing site data for the same counties of Pennsylvania and New Jersey.

A dramatic emphasis on terrace and floodplain landforms in the data reflects a clear settlement preference by native peoples, but also the survey bias of past amateur and professional field work (Riegel et al 1994:94). The average distance to nearest water is 78 meters while 70% of sites are within 100 meters of water, 13% are within 101-200 meters, and 8% are directly adjacent to water. Average distance to a stream confluence is 866 meters (Riegel et al 1994:95).

Additional survey work was designed to sample four types of landforms found within the park (Riegel et al 1994:104):

-upland stream sides, especially bluffs above streams and stream junctions;
-swamp margins with views of the Delaware River;
-lake margins, including areas with and without views of the Delaware River; and
-rock outcrops, especially areas where quarries might be found per geological analysis.

Sixty-eight sample areas ranging in size from 2.25 to 9.0 acres that embraced these settings were subsequently shovel tested (Riegel et al 1994:107, Tables 21, 22). The environmental coverage of the testing program and its results are summarized in Tables 26 and 27. Thirty-eight new sites were located.

TABLE 26
Acreage Equivalent of Environmental Zones Tested in the Riegel et al 1994 Survey of the Delaware Water Gap National Recreation Area*

State	Lake Margins Existing Acreage	Lake Margins Tested Acreage	Lake Margins Sites Found	Swamp Margins Existing Acreage	Swamp Margins Tested Acreage	Swamp Margins Sites Found	Stream Margins Existing Acreage	Stream Margins Tested Acreage	Stream Margins Sites Found
Pennsylvania	1028.2	38.36	12	426.7	18.02	4	2220.2	27.05	3
New Jersey	1031.7	29.20	2	871.8	44.97	11	2310.9	39.33	8
Totals	2059.9	67.56	14	1298.5	62.98	15	4531.1	66.38	11

*Modified from Riegel et al 1994:Tables 21, 24, 28.

TABLE 27
Sampling of Environmental Settings and Results of the Riegel et al 1994 Survey of the Delaware Water Gap National Recreation Area*

State	Lake Margin Areas in Sampling Universe	Lake Margin Areas Sampled	Lake Margin Sites Found	Swamp Margin Areas in Sampling Universe	Swamp Margin Areas Sampled	Swamp Margin Sites Found	Stream Margin Areas in Sampling Universe	Stream Margin Areas Sampled	Stream Margin Sites Found
Pennsylvania	27	13	12	10	8	4	32	12	3
New Jersey	22	10	2	14	11	11	33	14	8
Totals	49	23	14	24	19	15	65	26	11

*Source: Riegel et al 1994:240-249.

The results of the new survey and analysis of existing site data were compared with the predictive associations of the earlier work of Wall and Botwick (1995) and Bergman et al (1994/1996). The results can be summarized as follows, recognizing that lowland floodplain and terrace settings were not included:

-regarding upland stream side settings - terraces or bluffs overlooking upland streams under 600 feet in elevation are preferred locations for sites (Riegel et al 1994:250);

-ridgetop and overlook settings in association with a water source are predictable locations for archaeological sites (Riegel et al 1994:250-251);

-landscapes adjacent to upland swamps, at least on the New Jersey side of the river have a high potential for yielding prehistoric sites (Riegel et al 1994:252-253);

-only the margins of select lakes are the focus of Native American activity with additional features such as ease of access from lower elevations, other water sources, and lithic resources likely important (Riegel et al 1994:254); and

-rock outcrops can be the locus of Native American activities, especially the procurement of toolstone (Riegel et al 1994:255).

Tables 28-30 combine data from the surveys of Bergman et al (1994/1996), Riegel et al (1994), and Wall and Botwick (1995) to examine trends in landscape use and associations with

TABLE 28
Relation of Sites to Surface Water for Monroe, Northampton and Pike Counties, Pennsylvania and Warren and Sussex Counties, New Jersey*

Areas in Analysis	**Distance to Nearest Water Range (sites in analysis)**	**Distance to Nearest Water Mean**	**Distance to Nearest Water Median**	**Distance to Nearest Stream Confluence Range (sites in analysis)**	**Distance to Nearest Stream Confluence Mean**	**Distance to Nearest Stream Confluence Median**
PA & NJ	0-570 meters (n=255)	83.6 meters	100 meters	0-7000 meters (n=318)	903.8 meters	885 meters
PA Only	0-480 meters (n=162)	67.2 meters	75 meters	0-7000 meters (n=208)	792.1 meters	800 meters
NJ Only	0-570 meters (n=93)	112.3 meters	102.5 meters	0-5400 meters (n=110)	1114.9 meters	930 meters

*Data employed in calculations derived from Riegel et al (1994:Tables 4-14, 28) and Wall and Botwick (1995:Table 42).

TABLE 29
Incremental Distances to Surface Water for Sites in Monroe, Northampton and Pike Counties, Pennsylvania and Warren and Sussex Counties, New Jersey*

Sites In Analysis	**Sites 0-50 Meters to Nearest Water N/%**	**Sites 51-100 Meters to Nearest Water N/%**	**Sites 101-150 Meters to Nearest Water N/%**	**Sites 151-200 Meters to Nearest Water N/%**	**Sites 201-250 Meters to Nearest Water N/%**	**Sites 251-300 Meters to Nearest Water N/%**	**Sites >300 Meters to Nearest Water N/%**
PA & NJ (n=255)	135 52.9%	58 22.7%	20 7.8%	18 7.0%	4 1.5%	4 1.5%	16 6.2%
PA Only (n=162)	91 56.1%	40 24.6%	12 7.4%	9 5.5%	2 1.2%	2 1.2%	6 3.7%
NJ Only (n=93)	44 47.3%	18 19.3%	8 8.6%	9 9.6%	2 2.1%	2 2.1%	10 10.7%

*Data employed in calculations derived from Riegel et al (1994:Tables 4-14, 28) and Wall and Botwick (1995:Table 42).

TABLE 30
Site and Landform Associations in Monroe, Northampton and Pike Counties, Pennsylvania and Warren and Sussex Counties, New Jersey*

Area in Analysis	**Floodplain Sites in analysis, % of total**	**Terrace Sites in analysis, % of total**	**Island Sites in analysis, % of total**	**Upland Stream Sites in analysis, % of total**	**Upland Swamp Sites in analysis, % of total**	**Upland Lakes Sites in analysis, % of total**	**Hill Slope Sites in analysis, % of total**	**Hilltop Sites in analysis, % of total**	**General Uplands Sites in analysis, % of total**	**Totals**
PA & NJ	105 26.1%	162 40.2%	7 1.7%	10 2.4%	22 5.4%	10 2.4%	58 14.4%	10 2.4%	18 4.4%	402 99.4%
PA Only	92 34.8%	102 38.6%	2 0.75%	2 0.75%	5 1.8%	10 3.7%	35 13.2%	6 2.2%	10 3.7%	264 99.5%
NJ Only	13 9.4%	59 42.7%	5 3.6%	8 5.7%	17 12.3%	2 1.4%	22 15.9%	4 2.8%	8 5.7%	138 99.5%

*Data employed in calculations derived from Riegel et al (1994:Tables 4-14, 28).

surface water and stream confluences, irrespective of the culture periods involved. A larger sample of sites has an obvious impact on values when compared with the initial analysis of Wall and Botwick (see Tables 23-25). Mean and median values related to distances to surface water and stream confluence are noticeably different, in some cases dramatically different. What each continues to emphasize, however, are the differences between trends on the Pennsylvania side of the river versus the New Jersey side. What is more comparable are the percentages of sites within incremental distances of surface water. The larger of the data sets (see Table 29) indicates that a substantial majority of sites are found within 150 meters of surface water with percentages as follows:

-New Jersey and Pennsylvania sites = 83.4% of sites
-Pennsylvania Only = 88.1% of sites
-New Jersey Only = 75.2% of sites

Nonetheless, these observations continue to suggest somewhat different trends between Pennsylvania and New Jersey in the relationship of site settings to surface water. A detailed comparison of drainage nets might help to clarify why this difference exists.

Comparison of the landforms represented by site settings is made difficult by the different descriptors used by the investigators. However, terrace settings account for a similarly substantial percentage of sites. This equates to 30.6% of all sites in the Wall and Botwick compilation (see Table 23), and in the larger data set ranging from 38.6% to 42.7% of total sites depending on the analytic area employed (see Table 30). The association of sites with upland swamps is somewhat comparable (9.7% versus a range of 1.8% to 12.3%) with this type of environment more frequently used by native peoples on the New Jersey side of the river.

Philip Perazio and colleagues have a longstanding interest in the development of settlement models for the Pocono Uplands of Pennsylvania (e.g., Blomster et al 2000; Perazio 1994, 1996, 1998, 2008; Perazio and Pressler 2005). The area encompassed in model development includes portions of the Glaciated Low Plateau and the Glaciated Pocono Plateau found in Wayne, Pike, Monroe and Carbon counties. The model has been formulated and refined over the years based on the analysis of existing site data and the results of numerous archaeological surveys in the area. Summarized here is the latest perspective provided by Perazio (2008).

Focusing solely on environmental variables, horizontal and vertical distances to water, slope, aspect, soil drainage, and soil habitat potential were tracked for known sites. Ratings/numerical values were given to soils with different drainage characteristics. The same was done for how a particular soil reflects the potential for different types of plant and animal habitats (e.g., Perazio 2008:Table 7.6). Soil type is considered as proxy for habitat potential since "soils develop over long periods of time, the characteristics of any soil type may be expected to persist for some time after the particular conditions which gave rise to them are no longer present. In this sense, soil is a fossilized representation of past environments" (Perazio 2008:93). Rockshelters were excluded from the analysis "since their locations are determined at least in part, by factors other than those being examined here" (Perazio 2008:91).

Table 31 summarizes insights related to the association of sites with surface water. The mean distance to surface water in combination with one standard deviation, i.e., 185.3 meters, is accepted as the high probability limit for this variable in the most recent iteration of the Pocono Uplands model (Perazio 2008:92). In general it is obvious that a great majority of sites exist within 100 meters of a source of surface water. These observations favorably compare with the results of the analyses of Wall and Botwick (1995), Bergman et al (1996), and Riegel et al (1994) summarized previously.

TABLE 31
Horizontal Distance to Water in the Pocono Uplands Model*

Site Category	Distance to Water Sites in Analysis	Mean Distance to Water (meters)	Distance to Water Standard Deviation (meters)	Mean Distance to Water + Standard Deviation (meters)	Sites Within 1 Standard Deviation (n - %)	Sites Within 100 meters of Water (n - %)	Maximum Distance to Water (meters)
All Sites	281	69.8	115.5	185.3	257 - 91%	232 – 83%	1207
Archaic Sites	29	95.2	180.4	275.6	26 – 90%	24 – 83%	700
Woodland Sites	21	44.8	54.2	99.0	15 – 71%	18 – 86%	100

Adapted from Perazio 2008:Table 7.2.

Sites situated on, or within 500 meters of soils with high potentials for key plant and animal habitats account for approximately 61% of cases (Perazio 2008:94, Table 7.8). The importance of wetlands has been noted in earlier studies (Perazio 1994, 1996; Perazio and Presler 2005:37). Well drained soils are obviously important. The importance of the aspect or a setting's exposure to sunlight is equivocal. No single aspect appears to be favored. As a group northeastern, eastern, southern, and southeastern exposures are linked with the majority of sites (60.9% of 261 sites) for which data exists (Perazio 2008:93, Table 7.5).

The variables and variable states used to define high probability areas are summarized in Table 32. This version of the model has been very successful in defining and differentiating settings with high and low potentials for the occurrence of sites (Perazio 2008:98-99). A critical

TABLE 32
Pocono Uplands Model: High Probability Variables Revised*

VARIABLE	VARIABLE STATE
Horizontal Distance to Water	185 meters or less
Vertical Distance to Water	20 meters or less
Slope	10% grade or less; 14% with standard deviation
Aspect	northeastern, eastern, southern, or southeastern
Soil Drainage	excessively to moderately well drained
Soil Potential for Herbaceous Plants	good or fair
Soil Potential for Hardwood Trees	good or fair
Soil Potential for Woodland Wildlife	good or fair
Soil Potential for Open Land Wildlife	not applicable

Source: Perazio 2008:Table 7.12.

variable that is hard to capture with the type of environmental data available prior to fieldwork is micro-topography. “Small landforms, sometimes only a few meters across and often less than a meter above the surrounding terrain, have repeatedly proven to be the ultimate deciding factor regarding the presence or absence of upland Native American sites in the Poconos” (Perazio 2008:96). This observation should help to focus field efforts during the survey of high probability areas defined by the model.

Following a review of regional literature Baublitz, Harral and Basilik (1995; also see Baublitz et al 1995) identified a group of three variables determined to be critically related to upland site locations:

-slopes with a grade of less than 15% except where rock outcrops might indicate the presence of rockshelters;

-areas within 100 meters of a water source or associated with a stream heads, spring heads, or stream confluences; and

-well drained soils, excepting areas where modern land forming served to create wetlands or poorly drained conditions where none likely existed previously.

A number of other factors drawn from the regional literature, especially the work of Wall and Botwick summarized above, are noted as being important but are not included in the critical grouping. These include site associations involving swamp edges, ridgetops or overlooks, kame terraces, floodplain margins and foot slopes, ponds, swamps, streamside environments, and outcrops incorporating toolstone (Baublitz et al 1995:4). All were used in addition to the critical grouping to focus the survey of proposed highway alignments in the Marshalls Creek area of Monroe County, Pennsylvania.

Sixty-five sites were examined as part of the survey of the Marshalls Creek area. Survey results indicated that the modeled variables employed were applicable when considered in conjunction with the other important factors noted in the regional literature. The presence of chert sources in the project area had a dramatic impact on the number and distribution of sites found. Holocene terraces and kame terraces account for 65% of the landforms associated with sites. Associated soils are well drained. Distances of sites to nearest surface water range from 0-236 meters with a mean distance of 72 meters and median of 91 meters (Stinchcomb et al 2009:33, Table 2). In short, the results are comparable to those of earlier studies in the Upper Delaware.

Data were compiled for three watersheds in Northampton and Monroe counties in Pennsylvania in advance pipeline and trail CRM surveys (Hornum 2007; Hornum et al 2005). Floodplain and terrace landforms are favored loci for sites, with stream bench and hillslopes also common (Hornum 2007:6; Hornum et al 2005:41). A summary is provided in Table 33 of the relationship between sites and nearest surface water. Originally, information for the three watersheds reflects the database available in 2005 (Hornum et al 2005). Site associations for the second and third watersheds shown in Table 33 were updated in 2007 by Hornum (2007). The number of sites involved in the analysis increased from 88 to 106 (20% increase), and from 69 to

107 (55% increase), respectively. The change in sample size has dramatically impacted the relationship of sites to nearest surface water relative to the earlier analysis. Further, it is difficult to reconcile surface water associations reported for the watershed comprised of Marshalls, Brodhead, Pocono, and McMichaels creeks with data resulting from an analysis of sites in just the Marshalls Creek area (e.g., Baublitz et al 1995; Stinchcomb et al 2009). Distances to surface water appear to be greater for the latter.

TABLE 33
Surface Water Associations for Sites in Three Watersheds, Northampton and Monroe Counties Pennsylvania

Watershed (major creeks involved)	**Sites In Analysis 2005**	**Sites In Analysis 2007**	**Sites & Surface Water Associations 2005**	**Sites & Surface Water Associations 2007**	**Comments**
Shohola, Bushkill	139	n/a	~75% within 30.5 meters	n/a	Majority of sites within 24.4 meters of water (2005)
Marshalls, Brodhead, Pocono, McMichaels	88	106	~90% within 30.5 meters	~75% within 30.5 meters, 70% adjacent	Majority of sites within 15.2 meters of water (2005, 2007)
Martins, Oughoughton	69	107	data not provided	data not provided	Majority of sites within 24.4 meters (2005); majority of sites within 106.7 meters of water (2007)

*Data derived from Hornum (2007) and Hornum et al (2005).

In general, these data suggest that the relationship between sites and surface water probably varies between watersheds. What remains to be determined is the overall significance of this variation, and whether it results from the nature of the drainage nets in the watersheds or cultural factors. The spatial scale at which data are synthesized are critical to consider in developing or deploying models as best represented by the statewide models developed for Pennsylvania.

A survey effort in an area just west of Shawnee and adjacent to the Delaware Water Gap National Recreation Area (Monroe County, PA) envisioned likely site locations following a review of regional models and environmental data for known sites located within two miles of an 820 acre project area (Walker et al 2007). Data provided for nearby sites with relevant data (n=86, Walker et al 2007:Table 6.2) yields the following results regarding distance to water:

-Range = 0 to 289.5 meters (950 feet)
-Mean = 74.4 meters (244.3 feet)
-Median = 91.4 meters (300 feet)

As a result, settings with a high probability for the occurrence of archaeological sites were defined as relatively level, well drained ground within 100 meters of a stream and associated wetlands. Level areas/saddles between drainage divides are important loci even at distances greater than 100 meters (Walker et al 2007:7-2 to 7-3, Figure 4.5, Appendix B). Also taken into account in the designation of sensitivity areas was the extent to which disturbances associated with earthmoving activities may have affected the information value of undocumented archaeological resources in high potential areas (Walker et al 2007:7-1). An earlier study focused on central Monroe County (Hatch and Hamilton 1978:24) concluded that distance to a perennial water source is the single most significant factor in determining a site's setting with 93% (n=26) of sites within 200 meters of "one of the larger streams and 62% with a smaller secondary sources, usually a feeder stream, within 200 meters" (Hatch and Hamilton 1978:24).

Twelve high potential areas of varying acreage were defined and tested. Four of the tested areas contained deposits designated as eight distinctive sites, and three other areas produced isolated, artifact finds (Walker et al 2007:8-1 to 8-9). Considering the miscellaneous finds as well as the defined sites, ~58.% of the high potential areas identified yielded evidence of Native American activity. The investigators assert that the discoveries fit the expectations of models developed for upland areas (Walker et al 2007:8-35 to 8-36).

An extensive pipeline survey involving southwestern, southcentral, eastern and Upper Delaware Valley portions of Pennsylvania employed a single predictive model (Niemel et al 2008:42-46, Figure 2). Probability areas were defined as follows:

-High Probability Areas = within 50 meters of previously recorded site; landform with gradient of 15% or less within 200 meters of a water source, and regardless of soil productivity rating;

-Medium Probability Areas = landform with gradient of 15% or less between 200 and 300 meters of a water source, with high or medium soil productivity rating; and

-Low Probability Areas = landform with gradient of 15% or less between 200 and 300 meters of a water source, with low soil productivity rating; landform with gradient of 15% or less greater than 300 meters from a water source, and regardless of soil productivity rating; developed land.

In some respects using soil productivity ratings would capture some of the environmental diversity represented in the drainage basins and physiographic zones in this linear project area. Petyk et al (2010:49-50, 310) employed the same model for another linear project area in Pennsylvania but found the use of soil productivity ratings to be problematic as a predictive variable. Their model does not take into account data previously compiled for the Upper Delaware regarding the relationship between site settings and surface water. However, the liberal estimate of 200 meters used in the definition of high probability areas would capture relevant sites. Relatively unique in this modeling effort is the designation of sensitivity areas within 50 meters of a previously recorded site, the implication being that site boundaries may not have been determined sufficiently (Niemel et al 2008:42). The effectiveness of the model once the survey was completed was not evaluated.

A subsequent pipeline project involving portions of Wayne and Pike counties in Pennsylvania (Avery et al 2012) employed the same model as that of the Niemel et al (2008) and Petyk et al (2010) surveys. Soil productivity ratings continued to be used regardless of prior cautionary conclusions (Petyk et al 2010:310) regarding their effectiveness in modeling. Again, the effectiveness of the model once the survey was completed was not evaluated. Maps provided of survey areas are coded by probability areas and combine assessments of the potential for both historic and precontact cultural resources. So it is not possible to determine how many high, medium, and low probability areas relate specifically to expectations for the occurrence of precontact sites. However, report maps do provide some indication of the types of settings encompassed by the project's right-of-way.

Pipeline Loop 321 (8.14 miles/13.1 km) could involve 19 high probability areas based on the model's criteria and an inspection of topographic maps (Avery et al 2012:46-47, Table 1, Figures 29-31, 33). The potential high probability areas include landforms adjacent to wetlands, streams, or on either side of stream crossings. A single site, 36Pi252, was found containing a single Native American artifact. The site occupies an upland terrace adjacent to a wetland. Loop 323 (8.64 miles/13.94 km) also includes 19 of what could be construed as high probability areas (Avery et al 2012:Table 1, Figures 60, 61). Two sites occurred within the project area, 36Pi2 and 36Pi254. Site 36Pi2 is a floodplain locality associated with the Delaware River (Avery et al 2012:269). Site 3Pi254 occupies an upland slope/ridge overlooking a stream (Avery et al 2012:242-243, Figure 69). All discovered sites have settings that correspond with the expectations of the predictive model; however, there are numerous similar settings that were examined that produced no Native American archaeological deposits.

Notable in other more recent surveys in the Upper Delaware project area is the continued inclusion of previously identified sites as one factor in the designation of high probability areas for site occurrence. A linear transmission line project involving portions of Wayne, Pike, and Monroe Counties, Pennsylvania provides an example. Sensitivity evaluations were based upon the following criteria (Fortugno and Beadenkopf 2010:180-181):

> -High Sensitivity = landforms with slopes less than 15% and within 300 feet (91.4 meters) of surface water; areas within 300 feet of a previously recorded site;
>
> -Moderate/Low Sensitivity = landforms with slopes less than 15% and 300 to 1000 feet (91.4 to 304.8 meters) from surface water; areas within 300 to 1000 feet of a previously recorded site; and
>
> -No Sensitivity = disturbed landscapes confirmed by surface walkovers.

While assumptions about distance to surface water generally align with trends exhibited by the settings of known sites in the area, the effectiveness of the model was not evaluated at the conclusion of the survey.

As part of creating a context for a mitigation project Kudrle (2011) examined the settings of sites found in the sub-basin of the West Branch of the Delaware River in Pennsylvania and those of the West Branch basin in New York. Tables 34 and 35 summarize data compiled for the Pennsylvania portion of the drainage. Kudrle organized data by cultural historical components so it is not clear exactly how many individual sites are represented in the tabulations. Comparisons of the data with more southern portions of the Upper Delaware Valley project area must be done with caution but some observations are noteworthy.

TABLE 34
Landforms Associated With Sites in the West Branch Delaware Sub-Basin, Pennsylvania*

Landform	Components					
	Paleoindian #, % of all Paleoindian	**Archaic** #, % of all Archaic	**Transitional** #, % of all Transitional	**Woodland** #, % of all Woodland	**Unknown** #, % of all Unknown	**Totals** % of all Landforms
Ridgetop	0	1 (4%)	0	1 (3%)	1 (1.3%)	3 (2%)
Hilltop	0	0	0	0	1 (1.3%)	1 (0.5%)_
Hill ridge/toe	0	0	0	2 (5%)	2 (2%)	4 (2%)
Hillslope	0	2 (8%)	0	14 (38%)	24 (25%)	40 (23%)
Lower Slopes	0	0	0	0	1 (1.3%)	1 (0.5%)
Upland Flat	0	2 (8%)	0	1 (3%)	5 (5%)	8 (4%)
Floodplain	1 (100%)	17 (65%)	14 (93%)	14 (38%)	44 (45%)	90 (51%)
Stream Bench	0	0	0	1 (3%)	4 (4%)	5 (3%)
Terrace	0	4 (15%)	1 (7%)	4 (10%)	15 (15%)	24 (14%)
Total Components	1	26	15	37	97	176

*Adapted from Kudrle 2011:Table 10; percentages rounded.

TABLE 35
Sites and Distance to Surface Water in the West Branch Delaware Sub-Basin, Pennsylvania*

Distance to Water (meters)	Components					
	Paleoindian #, % of all Paleoindian	**Archaic** #, % of all Archaic	**Transitional** #, % of all Transitional	**Woodland** #, % of all Woodland	**Unknown** #, % of all Unknown	**Totals** #, % of all Components
0-100	1 (100%)	24 (92%)	15 (100%)	28 (76%)	78 (80%)	146 (83%)
100-200	0	2 (8%)	0	5 (15%)	12 (12%)	19 (11%_
200-300	0	0	0	2 (5%)	3 (3%)	5 (3%)
300-400	0	0	0	1 (2%)	1 (1.5%)	2 (0.75%)
>400	0	0	0	1 (2%)	2 (2%)	3 (2%)
No Data	0	0	0	0	1 (1.5%)	1 (0.25%)
Total Components	1	26	15	37	97	176

*Adapted from Kudrle 2011:Table 10; percentages rounded.

In the Pennsylvania portion of the drainage, floodplain and terrace settings account for 65% of component settings compared with 66.3% of sites situated in downriver areas. All upland settings account for 32% of components in the Pennsylvania West Branch sub-basin and 31.4% of downriver sites (compare Tables 30 and 34). It is interesting that if only New Jersey portions of downriver areas are considered floodplain and terrace settings account for 52.1% of sites and all upland settings for 43.8% of them. Although numerous biases affect the nature of the database these observations suggest the possibility of contrastive settlement patterns perhaps reflecting environmental differences found in the area. The relationship of site/component settings to surface water are somewhat equitable between the different areas. In the West Branch area 83% of components are within 100 meters of water compared with 75.6% of sites within 100 meters of water in downriver areas (compare Tables 29 and 35).

Comparing the above observations with data from 49 sites located in the New York portion of the West Branch basin is not exact owing to way in which landforms are characterized. Here valley floor settings, defined by landscapes with alluvial and glacial fluvial sediments, account for 65% of sites (Kudrle 2011:42, Table 11). This compares favorably with the percentages of sites associated with floodplain and terrace settings to the south and downriver. The remainder of known sites occur on more highly elevated landforms. The average site is within 61 meters of surface water (Kudrle 2011:42).

A survey in the Wallkill River Wildlife Refuge evaluated the settings of 80 sites. It was concluded that: 54% (n=43 sites) are situated within 100 meters of water; 40% (n=32 sites) are located between 130 and 400 meters from water, and 6% (n=5 sites) are located between 760 and 1000 meters from water. To capture a significant majority of sites (93.3%) a maximum distance of 400 meters would have to be employed in modeling sensitive locations (Kelly et al 2012:90, 92).

A review of predictive models employed in Pennsylvania and upland areas from other portions of the Middle Atlantic and Northeast regions served as a prelude to a highway survey in the Stroudsburg, Pennsylvania area (Brewer et al 2014, 2017), the most recent modeling effort reviewed for this report. In addition to a review of the literature, the settings of known sites in the Marshalls, Brodhead, Pocono, and McMichaels creeks watershed (Watershed 1E) were evaluated.

Landform associations of known sites within the watershed (Table 36) are comparable to other areas of the Upper Delaware with 53.7% of sites situated in a lowland setting (island, floodplain, rise in floodplain, terrace). Over 79% of sites are located within 100 meters of water (Table 37) which is at odds with earlier analyses of site settings in this watershed (Hornum 2007 Hornum et al 2005; see Table 33, this report). An increase in sample size has impacted results. The more recent analysis of Brewer et al (2014, 2017) is in accord with surface water associations documented throughout the Upper Delaware where a substantial majority of sites occur within 100 meters of water.

TABLE 36
Landforms Associated With Sites in the
Marshalls, Brodhead, Pocono, and McMichaels Creeks Watershed, Pennsylvania*

Landform	**Number of Sites**	**Percent of Total Sites (n=65) in Analysis**
Island	1	1.5%
Floodplain	13	20%
Rise in Floodplain	1	1.5%
Terrace	20	30.7%
Stream Bench	4	6.1%
Hillslope	3	4.6%
Lower Slopes	8	12.3%
Upper Slopes	3	4.6%
Saddle	4	6.1%
Upland Flat	4	6.1%
Ridgetop	4	6.1%

*Modified from Brewer et al 2014:Table 4.

TABLE 37
Distance of Sites to Surface Water in the
Marshalls, Brodhead, Pocono, and McMichaels Creeks Watershed, Pennsylvania*

Distance to Water (meters)	Number of Sites	Percent of Total Sites (n=128) in Analysis
0-25	82	64.0%
26-50	8	6.2%
51-100	12	9.3%
101-150	11	8.5%
151-200	6	4.6%
201-250	3	2.3%
251-300	2	1.5%
301-350	0	0
351-400	1	0.78%
>400	3	2.3%

*Modified from Brewer et al 2014:Table 3.

The model eventually developed for the highway survey is summarized in Table 38 and combines the analysis of watershed-specific data with insights derived from pre-existing models. Based on their review of predictive models for the region they concluded that elevation, aspect, and solar insulation have little to no predictive value (Brewer et al 2014:57). Limiting variables given greater weight in area assessments are slope, soil drainage, distance to any surface water, and previous disturbances (Brewer et al 2014:58). Proximity to lithic sources and historic trails were considered as important variables but were not applied in evaluating the sensitivity of project areas; no lithic sources are known for the vicinity and the exact location of the Pechoquealin Trail is somewhat obscure (Brewer et al 2014:59).

TABLE 38
Predictive Criteria in the Brewer et al (2014) Model, Monroe County, Pennsylvania*

Variables	Variable State for High Probability Areas	Variable State for Moderate Probability Areas	Variable State for Low Probability Areas
Percent Slope	0-8%	8-15%	>15%
Distance to 3rd or higher order stream	<100 meters	100-200 meters	>200 meters
Distance to lower order and intermittent streams	<75 meters	75-150 meters	>150 meters
Distance to stream confluence	<100 meters	100-200 meters	>200 meters
Distance to wetlands	<75 meters	75-150 meters	>150 meters
Soil drainage characteristics	Well drained	Moderately well drained to somewhat poorly drained	Poorly drained or hydric
Previously disturbed areas	n/a	n/a	Any disturbed area

*Modified from Brewer et al 2014:Table 7.

Critical distances to surface water depending on stream order are based on studies from other portions of the Delaware basin. In these earlier studies (Diamanti 1995; Hay 1993) the distance to 3rd or higher streams is noted as 150 meters and 100 meters from lower order streams. Other studies relying on data from Upper Delaware areas conclude that well drained landforms within 100 meters of any water source (streams of varying orders, springs, ponds, lakes, wetlands) qualifies as archaeologically sensitive. Designating areas within 100 meters of stream confluences as having a potential high probability for archaeological sites falls short of the greater distances reported in a number of studies reviewed above that tracked this variable in relation to known sites.

Approximately 119 acres of the 182 acre linear project area were deemed to be testable, with 4.9 acres qualifying as high probability. The latter figure represents dozens of high probability areas of varying size, with probability assignments including the potential for the occurrence of cultural resources of the historic period (Brewer et al 2017:95-96, 3654). The survey documented Native American artifacts in 8 different areas, 6 of which are associated with a high probability rating (Brewer et al 2017:Figures 20G, 20L, 20N, 20R, 20S). The effectiveness of the model was not evaluated at the project's conclusion.

B. Additional Comments Regarding Environmental and Cultural Variables

Schrabisch's (1917) survey of 100 rockshelters in New Jersey concluded that those chosen for occupation have overhangs ranging from 5 to 25 feet (1917:30). Proximity to a natural travel route is also considered to be a factor determining whether or not a shelter gets used (1917:31). In a 1919 article Schrabisch makes overarching statements about the nature and occurrence of rockshelters. A number of these synthetic statements contradict the data that can be derived from his basic descriptive reports. For example, he notes the predilection for natives to select shelters with a southerly exposure, yet data for shelters that he surveyed in the Pennsylvania portion of the Upper Delaware Valley (Schrabisch 1930) reveals a preference for eastern exposures.

Select data from Schrabisch's (1915, 1917, 1919, 1930) various surveys of Upper Delaware portions of Pennsylvania and New Jersey are summarized in Tables 39 and 40. Although his publications account for 84 shelters, 21 include no mention of surface water or state that surface water is not nearby. These 21 are not included in the tabulations of Table 39. The distance increments employed in Table 39 generally reflect breaks in the clustering of distances reported by Schrabisch.

TABLE 39
Surface Water Associations of Caves and Rockshelters Investigated by Max Schrabisch

Sites in Analysis	"Water Nearby"	30-150 ft 9.1-45.7 m	300-450 ft 91.4-137.1 m	600-900 ft 182.8-274.3 m	1200-1640 ft 365.7-499.8 m
63	39 61.9% of sites	4 6.3% of sites	9 14.2% of sites	7 11.1% of sites	4 6.3% of sites

TABLE 40
Aspect/Exposure of Caves and Rockshelters Investigated by Max Schrabisch

Sites in Analysis	Eastern	Western	Southern Southeastern Southwestern	Northern Northwestern
72	31 43% of sites	18 25% of sites	18 25% of sites	5 6.9% of sites

Over 82% occur within 138 meters of surface water, a measurement somewhat comparable to that which accounts for the majority of open air sites. Of the 63 rockshelters with a noted association with surface water, 13 (20.6%) are associated with a spring, 8 (12.6%) with a wetland or swamp, and 5 (7.9%) with a pond or lake. There is a slight preference for shelters with an eastern exposure. Eastern and southerly exposures account for the majority of sites. Schrabisch (1913a:40 1930) speculates that proximity to established open air camps influenced whether or not a shelter was used, and for what purpose.

In the Upper Delaware Valley above Port Jervis/Matamoras rockshelters (n=84) tend to be small with 3-5 feet of overhang and 10 feet wide or less (Dekin et al 1983:4-17). However, the larger the shelter, and the nearer it is to a water source, the greater its archaeological potential. Late Woodland components appear to be the most frequently represented in occupied shelters (Dekin et al 1983:4-18; see also Budinoff 1983).

Rockshelter size and stream order may influence surface water associations. The 10 Mile River Rockshelter at Narrowsburg, Sullivan County, New York is 50 feet long and 12 feet wide. It is located within 900 feet (274.3 meters) of the confluence of the Ten Mile River and the Delaware (Funk et al 1971:25). In downriver areas size alone does not seem to consistently determine whether a rock overhang is used in some fashion. This is most dramatically seen in the fieldwork of William Strohmeier in central and northern Bucks County, Pennsylvania (e.g. Strohmeier 1991). Strohmeier recorded a variety of sites that consisted of a handful of flakes or a few tools associated with massive boulders barely the size of an automobile (Pennsylvania Archaeological Site Survey files; Stewart 2005). The Simpson Mine site (28Sx412) represents a cluster measuring 20’x 20’ of artifacts near an isolated large rock (Lazazzera et al 2005:Appendix E).

In a study of 39 rockshelters in eastern New York Funk (1989:87-89) notes that west-facing shelters are occupied as frequently as east- or south-facing shelters. Aspect/exposure is not a consistent predictive variable for determining which shelters get used since the significance of aspect to occupants could vary depending on the season. Many shelters are situated less than 200 meters from streams, lakes or springs although others are found at distances greater than 200 meters. Convenience to natural travel routes may be a factor in the selection of some shelters for occupation.

Funk (1992) emphasizes the importance of landscapes adjacent to wetlands for the clustering of all types of sites in nearby sections of New York. The extensive black dirt area associated with the Wallkill River Valley of Orange County, New York and adjacent portions of New Jersey has a long history as a wetland. The area is unique for the large number of

Pleistocene mammals found including mastodons. During the 19th century it remained a large swamp that was subsequently drained and used for agriculture (Funk 1992:28). In the Upper Delaware evidence from a pond in northwestern New Jersey demonstrates the presence of fish species during the Late Pleistocene (Peteet et al 1993) emphasizing the potential attraction of such features to early and later Native Americans living in the area.

Kraft (1985:11) proposes that occupations on river islands are focused on the margins fronting the main channel, and not on secondary channels, sloughs or flood chutes separating them from the mainland. This possibility stems from his consideration of the archaeological deposits of Mashipacong and Kendrick's islands in the Upper Delaware and may not be supported by the archaeology of other islands. There are a variety of factors, natural and cultural, that might impact the differential use of island landscapes.

An assumption supported by the ethnography of hunter gatherers is that individuals or groups will forage within a reasonable travel distance of a residential base creating more ephemeral types of sites associated with the procurement and processing of resources (e.g., Binford 1982; Grove 2009; Kelly 1995:132-152). The distance traveled on daily, round trip forays will vary depending upon: the length of stay at a residential base and the season of residence; the topography and productivity of the regional environment; and the value or critical importance attributed to plant versus animal resources. New residential bases will be created well beyond the original base's foraging radius. In Binford's (1982:10) complete radius leapfrog pattern of hunter–gatherer movement the minimum necessary distance moved between residential bases is equal to twice the foraging radius (Figure 5). A maximum of 10-20 kilometers is suggested for the length of daily round trips forays made by hunter gatherers (Kelly 1995:133).

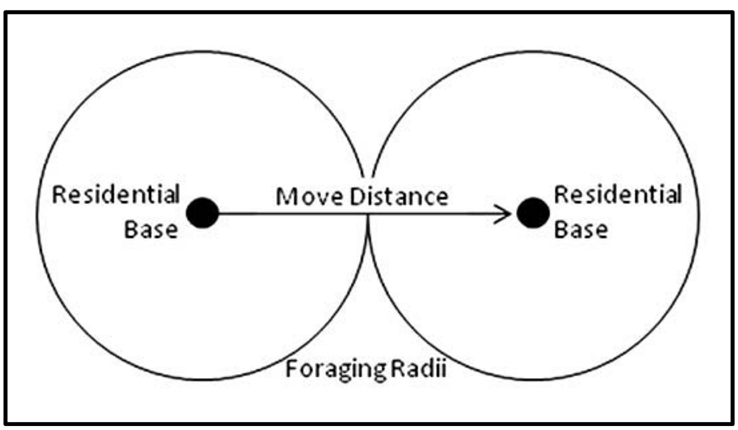

FIGURE 5. Binford's Leapfrog Pattern of Residential Bases and Foraging Radii. Modified from Binford (1982:Figure 2) and Grove (2009:Figure 1).

As part of a Warren County, New Jersey project Kalb et al (1981) use a series of small upland sites to define the foraging radius or catchment area of habitation sites located along the Lopatcong and Pohatcong Creeks near their mouths with the Delaware River. A catchment area measuring 2.7 to 4.5 miles (4.3 to 7.2 km) in a linear direction, or daily round trips of 8.6 to 14.4 kilometers is inferred. Interpreting site distributions along the Delaware River farther north in

Warren County Stevens et al (1993) suggest that distances from sites defined as potential base camps to those that might be outliers are 200 to 400 meters. Grills and Ebeling (1999:17) use the concept of foraging radii to develop expectations for a survey area in Wayne County, Pennsylvania. Key to applying this notion to archaeological surveys and predictive models is the location of known sites that could reasonably be interpreted as residential bases.

C. Period-Specific Observations

Although Marshall's (1982:Tables IV, V) predictive endeavor for Paleoindian sites in the Highlands and Ridge and Valley provinces of New Jersey can be critiqued her research isolated landscapes on which sites are expected to occur. These include: outwash plains, secondary streams and drainages, glacial kames and kame terraces, eskers, deltas, kettles and glacial lakes, bluffs and ridgetops. In addition to these environmental features high frequency occurrences of Paleoindian sites are expected to be associated with mucklands, swamps, and glacial drainages. The unique environment of the black dirt area of the Wallkill/Rondout Valley of New Jersey and New York may have been a draw for Paleoindians, as it was for late Pleistocene fauna (Lothrop, LaPorta et al 2018:292, 296, 304, 324-325).

The majority of Paleoindian sites in the New Jersey portion of the Upper Delaware project area are associated with terrace/floodplain settings (Pagoulatos 2004:Table 4). This does not seem to vary depending on the physiographic zone involved, as data from the West Branch Delaware sub-basin indicates when compared with that of more downriver portions of the project area (compare Tables 34, 39). Sites and find spots of fluted points cluster near the main stem of the Wallkill River (Lothrop, LaPorta et al 2018:324).

Considering only the Delaware Water Gap National Recreation Area (Table 41), Paleoindian through Middle Archaic sites tend to be situated in floodplain and terrace settings. In upland settings, Archaic and Late Woodland period sites are the most frequently encountered (Riegel et al 1994:97). The related frequency of Late Archaic, Transitional Archaic, and Late Woodland sites in floodplain and terrace settings could be taken as a fingerprint of lowland habitation sites linked to upland forays and procurement camps. Farther upriver in the West Branch sub-basin, the majority of Paleoindian through Transitional Archaic sites are riverine oriented. It is only during Woodland times that a broadening and more equitable use of lowland and upland settings is in evidence (see Table 34).

A 1995 analysis by Wall and Botwick (1995:243) for Pennsylvania and New Jersey portions of the Upper Delaware indicates that Paleoindian through Middle Archaic site locations are usually within less than 50 meters of surface water, with floodplain/terrace settings favored. Late Archaic sites are oriented toward, floodplain, terrace, and stream bench settings although they also occur on a number of upland landscapes. Distance to nearest water ranges from 0-420 meters with a mean distance of 75 meters (Wall and Botwick 1995:243, Table 42). The range for Transitional Archaic sites is somewhat less (0-340 meters) but the mean is similar to that for Late Archaic sites (72 meters). A wider variety of riverine oriented settings, including islands, beaches, and kame terraces, characterizes Transitional Archaic sites with a decrease in the variety of upland landscapes represented (Wall and Botwick 1995:243, 254,Table 42).

TABLE 41
Landform and Cultural Component Associations
Delaware Water Gap National Recreation Area*

LANDFORM	CULTURAL PERIOD COMPONENTS									
	Paleo-Indian	**Early Archaic**	**Middle Archaic**	**Late Archaic**	**Trans[2] Archaic**	**General Archaic**	**Early Wood[3]**	**Middle Wood[3]**	**Late Wood[3]**	**General Wood[3]**
Island	0	1	0	0	1	1	1	2	2	1
Floodplain	5	3	6	18	18	14	10	12	32	10
Terrace	7	12	5	28	24	18	10	9	42	10
Hillslope	0	0	0	6	5	7	5	1	16	2
Hilltop	0	0	0	1	1	1	0	0	0	1
Upland	1	1	1	6	1	2	0	0	5	0
Swamp/pond[1]	0	0	0	4	0	1	4	0	4	1
Totals	13	17	12	63	50	44	30	24	101	25

*Adapted from Riegel et al 1994:Table 16. 1=upland association 2=Transitional 3=Woodland

Early and Middle Woodland sites are found nearer surface water than those of earlier cultural periods. The mean distance for Early Woodland sites is 45 meters with a range of 5-160 meters. The mean distance for Middle Woodland sites is 57 meters with a range of 5-200 meters. Settings for both Early and Middle Woodland sites are highly riverine oriented. A majority of Late Woodland sites are riverine oriented but are also associated with upland swamps, upland flats, and hillslopes. The distance to nearest surface water ranges from 0-480 meters for Late Woodland sites with a mean of 61 meters (Wall and Botwick 1995:254).

In the analysis of Wall and Botwick, the majority of sites for all cultural periods are situated within 100 meters of some type of surface water. However, changes in the more precise values of this variable by cultural period suggest differences, perhaps subtle, in settlement patterns over time. Paleoindian through Middle Archaic sites are situated closer to water than those of the Late and Transitional Archaic. Woodland period sites more closely mimic the settings of Paleoindian through Middle Archaic ones with respect to water.

Existing site data compiled by Bergman et al (1994/1996) for the Delaware Water Gap park were collapsed into the categories of Paleoindian, Archaic, Woodland, and Unidentified for additional analysis. Sites of all cultural categories are most frequently found 100 meters or less from surface water, and less than 400 meters from a stream confluence (Riegel et al 1994:100). Chi-square tests of independence were run using each of the cultural categories and the variables of landform, slope, elevation, distance to water, and distance to nearest confluence. Results indicate that the variables and cultural categories are not independent but associated (Riegel et al 1994:100-101). Distance to surface water data captures the trends, if not the nuances, of similar studies with respect to the association of sites and surface water (Riegel et al 1994:98; Table 42, this report). Paleoindian and Middle Archaic sites tend to be located nearer confluences than those of other cultural periods. Proportionately, Early Archaic sites located at distances greater than 2000 meters from a stream confluence stand in contrast to trends exhibited by components of other period (Rigel et al 1994:98; Table 43, this report).

TABLE 42
Nearest Water and Cultural Component Associations
Delaware Water Gap National Recreation Area*

Distance to Water (meters)	CULTURAL PERIOD COMPONENTS									
	Paleo-Indian	Early Archaic	Middle Archaic	Late Archaic	Trans[1] Archaic	General Archaic	Early Wood[2]	Middle Wood[2]	Late Wood[2]	General Wood[2]
adjacent	4	2	3	6	4	3	1	0	7	0
up to100	5	7	7	35	26	17	21	15	56	6
101-300	1	1	1	6	6	8	2	2	11	2
>300	0	0	0	3	2	1	0	0	4	0
Totals	10	10	11	50	38	29	24	17	78	8
% sites≦100m	90%	90.%	90.9%	82%	78.9%	68.9%	91.6%	88.2%	80.7%	75%

*Adapted from Riegel et al 1994:Table 18. 1=Transitional 2=Woodland

TABLE 43
Nearest Stream Confluence and Cultural Component Associations
Delaware Water Gap National Recreation Area*

Distance to Confluence (meters)	CULTURAL PERIOD COMPONENTS									
	Paleo-Indian	Early Archaic	Middle Archaic	Late Archaic	Trans[1] Archaic	General Archaic	Early Wood[2]	Middle Wood[2]	Late Wood[2]	General Wood[2]
adjacent	2	2	2	1	2	0	0	0	2	0
up to 400	4	3	5	16	17	14	14	12	36	13
401-800	0	3	0	10	5	5	2	4	17	3
801-1200	0	1	1	9	6	6	4	1	13	3
1201-2000	0	0	0	5	9	5	4	3	11	3
>2000	1	6	1	7	3	6	2	1	4	3
Totals	7	15	9	48	42	36	26	21	83	25
% sites≦400	85.7%	33.3%	77.7%	35.4%	45.2%	38.8%	53.8%	57.1%	45.7%	52%
% sites≦800	85.7%	53.3%	77.7%	56.2%	57.1%	52.7%	61.5%	76.1%	66.2%	64%
% sites≦1200	85.7%	60%	88.8%	75%	71.4%	69.4%	76.9%	80.9%	81.9%	76%
% sites≦2000	85.7%	60%	88.8%	85.4%	92.8%	83.3%	92.3%	95.2%	95.1%	92%

*Adapted from Riegel et al 1994:Table 19
1=Transitional 2=Woodland

A provisional toolstone sourcing study of Paleoindian bifaces implies that the Rondout/Wallkill river valley served as a probable travel route for Paleoindians (Lothrop, LaPorta et al (2018:292), echoing earlier speculation by Kraft (1973:64). The Wallkill River, which has its headwaters in Sussex County, New Jersey, is the only north flowing tributary of the Hudson River and provides a geographic link between the Hudson and Delaware valleys. Assuming that toolstone was directly procured rather than traded for, it is suggested that:

> fluted point groups likely moved through the Wallkill Valley on seasonal travels, both northward from the Middle Delaware Valley and southward from the mid-Hudson Valley. The differences in the dominant raw material between individual sites may indicate variation in the magnitude of Paleoindian seasonal movements and/or in the scheduling of lithic procurement during their travels (Lothrop, LaPorta et al 2018:324).

In a subsequent study Lothrop et al (2018) test speculation about the use of natural travel routes by Paleoindians using least cost analysis in conjunction with XRF sourcing of Paleoindian artifacts made with Normanskill chert. Artifacts from the Plenge and Poirier sites from the Upper Delaware project area were part of the sourcing analysis and linked by XRF to Normanskill sources in the area of West Athens Hill/Kingston, New York. Other project area and greater Delaware Valley Paleoindian sites with Normanskill artifacts were included in the pathways analysis but not all were part of the sourcing portion of the study. These sites include Dutchess Quarry Cave #1, Zierdt, Beaver Lodge, Wolverton, Snyder Cache (Hoffman site), Nesquehoning Creek, and Pocono Lake (Lothrop et al 2018:Figure 1, Table 1). Sites located between 100 and 390 kilometers from the generalized West Athens Hill source area, representing diverse terrains, and possessing assemblages where Normanskill chert is the dominant or most common minority toolstone were defined as "destination" sites (Lothrop et al 2018:472). The Poirier site in the Upper Delaware Valley was considered to be one of these.

Two approaches were taken in assessing least cost pathways between source areas and destination sites. Paths of least resistance (least slope pathways) typically involve valleys and lowlands. A second approach used a "hiking function" algorithm to solve for travel time - the fastest pedestrian route between source areas and destination sites. These are referred to as Tobler's pathways in recognition of the individual who developed the algorithm. Such routes include uplands and follow valleys, lowlands, and the regional topographic grain only when they coincide with the overall axis of the route (Lothrop et al 2018:463, 470-475, 479, Tables 3-4, Figure 5, Supplemental text).

Least Slope and Tobler's paths follow somewhat similar and overlapping routes to the Poirier site moving south down the Hudson Valley and through the Wallkill and Paulinskill river drainages into the Upper Delaware (Figure 6). Table 44 shows the relationship of other Paleoindian sites to these proposed routes. The study reinforces the importance of travel routes in understanding the distribution of known sites and its potential in predicting where additional sites might be found. It also re-emphasizes the importance of the Wallkill River Valley as a transportation corridor and the possibility that the density of sites will be greater than in adjacent areas.

TABLE 44

Closest Distance Between Pathways and Non-Destination Paleoindian Sites with Normanskill Chert Artifacts*

Poirier Pathway and Related Sites	Closest Distance to Least-Slope Path (km)	Closest Distance to Tobler's Path (km)
Twin Fields, NY	0.54	2.85
James Decker, NY	2.41	9.22
Soon's Orchard, NY	0.80	4.07
Dutchess Quarry Cave #1, NY	3.06	8.57
Zierdt, NJ	16.25	16.28
Pocono Lake, PA	49.03	46.97
Nesquehoning, PA	54.08	54.08
Plenge, NJ	16.41	18.02
Wolverton, NJ	17.05	18.41
Snyder Cache, NJ	23.73	24.0

*Abstracted from Lothrop, Burke, Winchell-Sweeney and Gauthier 2018:Supplemental Table 2

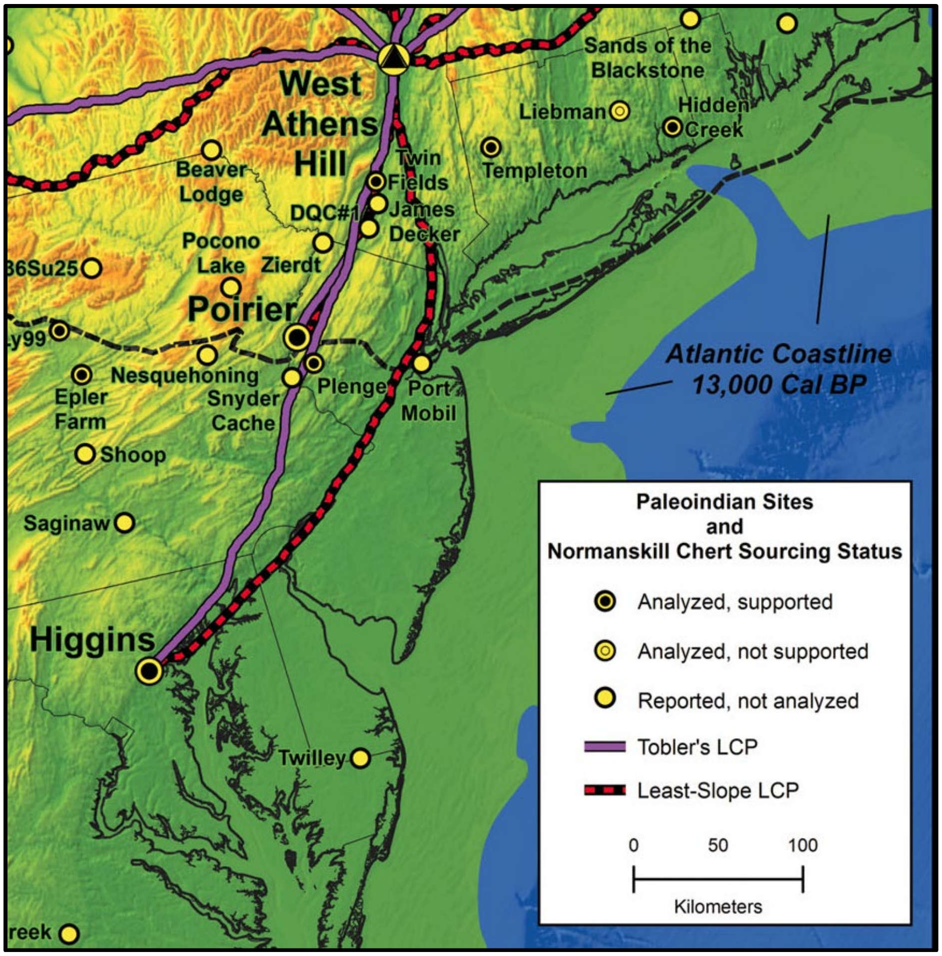

FIGURE 6. Least Cost Pathways from the West Athens Hill Source Area for Normanskill Chert to the Poirier Paleoindian Site in the Upper Delaware Valley. Note the substantial overlap of the Least Slope and Tobler's paths to the site. Modified from Lothrop, Burke, Winchell-Sweeney and Gauthier (2018:Figure 5).

Although they are poorly represented in the Upper Delaware Valley, Early Archaic sites appear with greater frequency, and in a greater variety of environments, than do those of the Paleoindian period. Sites of the Middle Archaic period continue the trend of earlier Archaic times by occurring in a variety of environmental settings. The importance of lithic sources for influencing settlement locations and movements appears to be de-emphasized relative to Paleoindian and Early Archaic times (Wall and Botwick 1995:17-18).

Perazio's (2008:96) analysis of Archaic and Woodland sites on the Pocono Plateau (see Tables 31 and 32 above) reveals that some Archaic sites seem to be located at greater distances from water than Woodland sites. The habitat potential of associated soils and their juxtaposition with poorly drained soils suggests that Archaic sites are set in generally more diverse and biologically productive habitats than those of Woodland times (Perazio 2008:95-96). In contrast, slope and aspect data suggest a wider range of tolerance for variation in these characteristics by Woodland peoples when compared with Archaic groups.

Upland/mountain springs and ponds are noted as a foci of Archaic sites in the Highlands portion of southern project areas, with rockshelters typically associated with springs, lakes or marshes (Kraft and Mounier 1982a:63). In the Kittatinny Valley Archaic sites are often located in gaps through the southwest to northeast trending ridges that characterize the area and help to define natural travel routes (Kraft and Mounier 1982a:63).

During the Late Archaic period an increase in the use of upland/interior settings in the Delaware Water Gap National Recreation Area can be noted complementing a marked riverine focus of settlements. Within a two mile (3.2 km) radius of presumed base camps hunting and procurement related sites are found (Walker et al 2007:8-37; Wall and Botwick 1995:19, 243).

Components of the Delaware Valley Late Archaic II Complex (i.e., broadspear-related) in the Upper Delaware reveal an intensification of the use of floodplains and river terraces in comparison with components of the Delaware Valley Late Archaic I Complex (Custer 1996:203). In an analysis of the greater Delaware Valley Wholey (2015:114-115) asserts that all Upper Delaware Transitional Archaic sites are located within 200 meters of the nearest surface water, a smaller distance than what is associated with Transitional sites in downriver areas. This generalization can't be reconciled with previous assessments of surface water associations in the Upper Delaware (see Tables 35, 42, 43).

Blondino (2015) examined the relationship between Orient sites situated in near-river environments with other streams for Pennsylvania portions of the valley from the Lehigh River confluence upriver to Matamoras. The assumption examined is that the combination of riverine floodplain/terrace settings and adjacent streams could reflect the importance of plant resources. Orient sites exhibit an apparent preference for settings involving low order streams, potentially because of the wetland ecology often associated with them (Blondino 2015:102-105). Distances to secondary streams are summarized in Table 45 and could serve to refine predictions regarding site locations in floodplain or terrace settings.

TABLE 45
Distance of Orient Sites in Floodplain/terrace Settings to Secondary Streams in the Upper Delaware Valley of Pennsylvania*

Number of Sites In Analysis	**Distance to Nearest Stream (meters)**		
	Range	Mean	Median
25	5 - 960	224.6	120

*Data abstracted from Blondino 2015:Table 5.2

Like other cultural periods, the majority of Middle and Late Woodland sites are located in lowland and terrace settings (e.g., see Table 41). There is some indication that the relationship of Middle Woodland site settings with stream confluences more closely resembles that of Paleoindian through Middle Archaic sites than those of other periods (see Table 43). Using hypothetical foraging radii should prove useful in anticipating small and upland sites related to Late Woodland residential bases typically situated in floodplain and terrace settings. The widely acknowledged semi-sedentary to sedentary nature of these residential bases theoretically would involve larger foraging radii and higher densities of ephemeral types of sites found within them in contrast to earlier periods. The frequency with which rock overhangs within a foraging radius are targeted for use might also be expected to increase.

As part of developing and testing hunter gatherer settlement models for nearby portions of the Upper Susquehanna Valley in New York (Delaware and Otsego counties), Versaggi (1987:7, 77-112, 263-279) identified environmental areas that represent seasonally aggregated and seasonally dispersed plant and animal resources. Stream confluences constitute a significant resource aggregation area and as a result of her site analysis are interpreted as a focus of Late Archaic residential cores (Versaggi 1987:297). These observations are somewhat at odds with data from the Upper Delaware given the distances of known sites from stream confluences (see Tables 24, 28, 43). In these cases, however, site types/function are not considered when summarizing the relationship between sites and stream confluences.

Funk (1993:Tables 26, 27, 28) charts the association and frequency of specific cultural historical components with environmental settings within the major environmental zones (Valley Floor, Valley Walls, and Uplands) of the Upper Susquehanna Valley in New York. Table 46 abstracts and recombines Funk's data for examples of components represented in the Valley Floor environmental zone, since the number of sites involved is significant relative to those of the Valley Walls and Uplands zones. It is important to recall that the Valley Floor zone makes up only 7.6% of the Upper Susquehanna study area considered by Funk; the Uplands zone represents the greatest percentage (85.2%) of the area (Funk 1993:Table 22). Selected examples of components are represented by diagnostic bifaces and pottery that are found with some frequency in the Upper Delaware project area. Although not a comprehensive reiteration of Funk's analysis, each of the cultural historical periods of regional prehistory are represented by the examples with an emphasis on those that reflect the greatest number of sites.

Notable in these data is the large number of sites associated with Brewerton and Lamoka components of the late Middle Archaic and Late Archaic periods. Such dramatic increases in site numbers is a trend seen in the broader Middle Atlantic Region and presumed to reflect to some degree an increase in the size of the Native American population (e.g., Carr 2015:Figures 3.6, 3.7; Carr and Moeller 2015:90-93; Wholey 2009). Also notable is the focus of Orient settlements on terraces and swamps/bogs associated with floodplains. In some respects this mirrors Blondino's (2015) analysis of Orient/Fishtail-related sites in the Upper Delaware Valley. Meadowood components also exhibit a similar pattern to Orient sites in the Upper Susquehanna Valley. Data dealing with sites found on alluvial fans of tributary streams implies that certain types of stream confluences may not be a significant predictor of site locations. However, all stream confluences need not be associated with alluvial fans. Versaggi (1987) has argued for the importance of such settings during the Late Archaic period.

D. Summary

Approaches used in the formulation of predictive models employed in surveys in the Upper Delaware Valley run the gamut from relatively simple to complex. While not addressed in the discussions above, the use of GIS in modeling efforts has increased through time. Pennsylvania's CRGIS allows registered users to search and manipulate site file data and access a growing number of digital reports. New York also makes available online a variety of survey

TABLE 46
Examples of Cultural Historical Affiliations and Site Settings on the Valley Floor of the Upper Susquehanna River, New York*

Component or Phase	No. of Sites	All Terrace types, Outwash Plains, Kame Deltas 0-100 meters to river No. Sites - Percent	All Terrace types, Outwash Plains, Kame Deltas >100 meters to river No. Sites - Percent	Isolated Knolls and Ridges 0-100 meters to river No. Sites - Percent	Swamp/Bog Association No. Sites - Percent	Alluvial Fan of Tributary >100 meters to river** No. Sites - Percent	Lake Association No. Sites - Percent
Paleoindian	14	8 – 57.1%	4 – 28.5%	0 – 0%	0 – 0%	0 – 0%	1 – 7.1%
Palmer	1	1 – 100%	0 – 0%	0 – 0%	0 – 0%	0 – 0%	0 – 0%
Kirk CN	2	2 – 100%	0 – 0%	0 – 0%	0 – 0%	0 – 0%	0 – 0%
Bifurcate	14	11 – 78.5%	1 – 7.1%	0 – 0%	1 – 7.1%	0 – 0%	1 – 7.1%
Neville	4	4 – 100%	0 – 0%	0 – 0%	0 – 0%	0 – 0%	0 – 0%
Brewerton	54	33 – 61.1%	13 – 24.0%	0 – 0%	5 – 9.2%	0 – 0%	3 – 5.5%
Lamoka	83	56 – 67.4%	15 – 18.0%	1 – 1.2%	4 – 4.8%	2 – 2.4%	5 – 6.0%
Snook Kill	21	13 – 61.9%	4 – 19.0%	0 – 0%	2 – 9.5%	1 – 4.7%	1 – 4.7%
Perkiomen	12	7 – 58.3%	3 – 25.0%	0 – 0%	1 – 8.3%	0 – 0%	1 – 8.3%
Orient	31	18 – 58.0%	7 – 22.5%	0 – 0%	4 – 12.9%	1 – 3.2%	1 – 3.2%
Meadowood	24	17 – 70.8%	2 – 8.3%	0 – 0%	4 – 19.0%	1 – 4.1%	0 – 0%
Bushkill	1	1 – 100%	0 – 0%	0 – 0%	0 – 0%	0 – 0%	0 – 0%
Fox Creek	15	10 – 66.6%	4 – 26.6%	0 – 0%	0 – 0%	1 – 6.6%	0 – 0%
Carpenter Brook	10	7 – 10%	3 – 30.0%	0 – 0%	0 – 0%	0 – 0%	0 – 0%
Garoga	14	10 – 71.4%	1 – 7.1%	1 – 7.1%	1 – 7.1%	0 – 0%	1 – 7.1%

*Abstracts and recombines data from Funk 1993:Table 26
**No sites associated with tributary alluvial fans are within 100 meters of the river.

through mitigation reports that makes it easier to review previous research in the process of developing expectations for areas to be surveyed.

A standard set of variables have been employed over time in models used to predict the potential of project areas to contain archaeological sites. Like most models in use in the broader region, a well-drained landform in proximity to surface water and/or a wetland are seen as significant variables for predicting site locations. Critical distances of site settings to surface water or wetlands varies depending upon the size and nature of the geographic area for which is being summarized and the sample size of sites employed in the analysis. Data from the nearby Upper Susquehanna Valley indicates that distances to surface water vary depending upon the type of landscape on which a site occurs.

Aspect/exposure and elevation are not consistently tracked by modelers but are thought not to be significant variables. Aspect or exposure might logically vary depending on site type, the length and season of occupation. This observation applies to both open sites and rockshelters. Predicting the location of rockshelters is problematic for a variety of reasons, one of which is that there are often many more potential shelters in an area than those proved to be used at some point in the past. Further, rock overhangs are subject to change over time such that more ancient ones might not be easily distinguished during surveys. There is some indication that proximity to open air residential sites or travel routes might increase the likelihood that a shelter gets used (e.g., Stewart 2005).

A number of modeling efforts employ pre-field evaluations of the degree to which areas to be surveyed have been disturbed. While there are obvious cases in which this can safely be done (e.g., historic or modern quarries), the results of urban archaeology have taught us that sites or site remnants can be preserved in cases where historic/modern development has been intensive.

The importance of stream confluences seems to be equivocal, or is considered as such by many modelers. Proximity to lithic resources or historic trails may, or may not be used in a given model depending upon an investigator's perception of the quality of available data; most would agree that sources of toolstone are important to consider when they exist within a project area. The habitat potential represented by the soil series mapped for an area has been considered important by some and unimportant by others. It strikes me that while soil potential might not be a valuable predictor for the exact setting of a site, it is useful to some degree in characterizing and ranking the environmental potential of the broader landscapes within which individual sites occur. Hatch and Stevenson (1981:16) caution that published soils data may not adequately reflect highly localized, productive settings that would be a draw for native settlement and activities., and could only be identified as a result of field survey.

Only rarely has the predictive value of variables been evaluated against the overall occurrence of comparable non-site settings in the natural environment of a project area. For example, in an area with a spatially dense drainage network and a plethora of wetlands, the predictive power of surface water and wetland associations is arguably lessened, implicating the enhanced importance of other environmental and cultural factors in identifying potential site locations. In far too many cases the utility of the model used to focus field work was not evaluated based on the results of the completed survey.

The value of variables like distance to surface water and stream confluences, and the use of specific types of upland environments, change through time and are important in understanding settlement patterns. However, given that settlement patterns of the Late Archaic through Woodland periods embrace the greatest range of environmental settings, models capable of capturing their site settings would essentially be effective in locating many sites dating to earlier periods.

The use of extensive combinations of variables, assessed against the background of specific environmental zones and in conjunction with regression analysis (Harris et al 2014c), has the potential to be more effective in modeling than approaches relying on the subjective use of a small number of variables. Both approaches are heavily reliant on the environmental associations of known sites. This is problematic since in most cases site databases are not derived from systematic surveys of the environmental diversity found in a particular geographic area.

Characterizing the overall resource potential of spatial units used to organize a project area (e.g., Bailey and Dekin 1980; Dekin et al 1983) emerges as a necessary first step in the modeling process, to be followed by employing the variables commonly associated with known sites to narrow down potential locations within highly ranked units (e.g., Curtin 1981). For me, this seems to be an equitable blend of deductive and inductive approaches to modeling site locations, and initially does not rely on the quality of the existing site database. The use of soils data as proxies for habitat and resource potentials, following the work of Philip Perazio and colleagues, would enhance the ranking of the resource potentials of survey areas in this two step process.

IV. DISCUSSION AND RECOMMENDATIONS

It is impractical to summarize all of the insights embedded in previous discussions here. Instead select, overarching topics are examined with recommendations for future practices.

A. Survey Goals, Field Methods, Site Size and Significance

In modeling the potential locations of archaeological sites basic questions that need to be addressed are what types of sites do we need to find; do we need to find every site in a project area; and what constitutes a site? These questions are important because of their connection with sampling strategies, and the ability of field methods to detect archaeological sites of varying sizes, types, and subsurface contexts.

From the perspective of cultural resource management, federal law and regulations provide guidance that is generally emulated by states (e.g., King 2000:50-52; PA SHPO 2017:9). Per regulations related to the National Historic Preservation Act (NHPA 1966, amended 1980, 1986, 1999), agencies involved in federal undertakings must consider the undertaking's impact on historic properties (Advisory Council on Historic Preservation-ACHP 2017). A historic property (or historic resource) is defined in the NHPA [54 U.S.C. § 300308] as any "prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion on, the National Register of Historic Places, including artifacts, records, and material remains related to such a property or resource (ACHP 2019). In relation to the archaeology of Native Americans "a site is the location of a significant event, a pre-contact or historic occupation or activity…" (USDOI, NPS 1997:5). Regulations do not require the identification of all archaeological sites within a project area, simply that agencies make a "reasonable and good faith effort" to identify historic properties, including archaeological sites, listed or eligible for listing on the National Register (ACHP 2019; King 2000:50-51).

In Pennsylvania (PA SHPO 2017:56) the minimum criteria for defining a site are:

- two or more culturally modified objects (points, flakes, stone tools, pottery sherds, etc.), excluding fire-cracked rock (FCR), when found within a 50 ft (15 m) diameter area when surface collecting a plowed field, or when recovered from an individual or adjacent shovel tests/units spaced no more than 50 ft (15 m) apart;

- the presence of any subsurface culturally derived feature; and

- a rock shelter containing at least one pre-contact artifact (excluding FCR).

Isolated artifact finds are considered to be important information for understanding native land use. While not assigned site numbers they are given a unique identifying number for curation purposes and appear on database maps along with sites. While acknowledging the usefulness of sampling, "the methodology of a Phase I survey should be adequate to make it probable that all potentially eligible sites will be recorded" (PASHPO 2017:9).

In New Jersey archaeological sites are defined as places where there are physical traces of people's past activities without regard to size or other definitive criteria (NJHPO 2018: Section 3.0). For example, site 28Sx274 is defined on the basis of the recovery of two flakes (Fittipaldi 1980); 28Sx455 on the basis of a single flake (Site files, New Jersey State Museum). In contrast, another project in Sussex County recovered 15 chert flakes over a linear area of 300' and was not considered as a site (Lenik 1987:24) suggesting variability in how the concept is employed by investigators and potentially reflected in the state's database.

In sum, investigators don't need to find all sites in a project area but must make a reasonable effort to find sites that may be, or are significant for inclusion in the National Register of Historic Places. Obviously predictive models are crafted without regard to the potential significance of sites as they intrinsically rely on data associated with known sites of all sizes, types and ages. Isolated finds of artifacts seem to play no role in this effort but arguably might contribute to it. It is how sensitivity areas or units designated by models are tested that raises potential problems with the mandate to make a reasonable effort to identify potentially significant sites and providing an adequate test of the model employed. Testing intervals of 50', a standard used in both Pennsylvania and New Jersey, may not be effective for locating small, potentially significant sites. And in failing to locate small sites, the utility of a predictive model cannot reasonably be evaluated.

Table 47 provides examples of the dimensions and contents of small sites from the greater Upper Delaware project area. Where only the area (in square feet or square meters) is reported I have translated that into a roughly square horizontal boundaries. There is substantial diversity in what can be characterized as small sites. There are a variety of assemblages from different cultural periods. Some sites are stratified and multicomponent, some without diagnostic artifacts but arguably representing a single component. Current field practices can obviously result in the discovery of small sites. But it also should be obvious that a variety of factors, including field methods and testing intervals, can lead to an unknown number of small sites going undetected during a survey.

In addition to field conditions, other factors affecting the discovery of archaeological deposits have been reviewed by Schiffer et al (1978; also see Banning et al 2017:472-473; Stewart 2002:205-218) and include:

-abundance, i.e., the frequency or prevalence of a site or type of artifact within a given area; density of archaeological deposits per unit area;

- obtrusiveness, i.e., the ease with which a site or artifacts can be detected using a particular discovery technique;

- visibility, i.e., the ease with which something can be seen; and

- accessibility, i.e., the effort required to reach an area or location.

Stewart (2002:285-289) summarizes a variety of sources dealing with the discovery of subsurface deposits in particular. The early work of Krakker et al (1983), summarized in Kintigh

TABLE 47
Examples of Small Sites in the Upper Delaware Valley Project Area

Site	Area in Feet and (meters)	Comments	References
28Sx412	20' x 20' (6.09 x 6.09)	Brewerton Eared biface, argillite, metarhyolite flakes	Lazazzera et al 2005:41, Tables 5.2, 5.3, Appendix E
28Sx432	30' x 15' (9.14 x 4.57)	10 artifacts recovered	Kratzer 2007:41, Figure 17
28Sx454	12.3' separates artifacts (3.75)	I jasper and 2 chert flakes	Site files, New Jersey State Museum
28Sx458	14.1' x 14.1' 200 ft²	Bare Island and Triangular bifaces, end scraper, flakes, core	McHugh 2010; Richard Grubb & Associates 2010
28Wa529	43.6' x 43.6' (176.71m²)	quarry-related Transitional Archaic workshop	Kardas and Larrabee 1980
28Wa603	n/a	isolated find of Late Archaic biface	Site files, New Jersey State Museum
Lithic scatter Warren Co. NJ	22.9' x 16.4' (7 .0 x 5.0)	utilized flake, 2 flakes	Fetzer et al 2002:4-15, 4-25
36Pi256	16.4' x 16.4' (25m²)	bifacial tools, flakes, FCR, hearth	Petyk et al 2011:87-95
36Mr71	18' x 12' (5.48 x 3.65)	2 Fishtail bifaces, 16 scrapers, anvil, debitage	Blomster and Perazio 1999:9-11
Broken Point Monroe Co. PA	50' x 40' (15.24 x 12.19)	Lackawaxen and Triangular bifaces (2), flake tool, 4 scrapers	Blomster and Perazio 1999:13-16
36Mr187	24.6' x 24.6' (7.50 x 7.50)	2 artifacts	Hornum et al 2005:169
36Mr188	24.6' x 24.6' (7.50 x 7.50)	2 artifacts	Hornum et al 2005:169
36Nm197	25' x 25' (7.62 x 7.62)	5 artifacts	Hornum et al 2005:79
36Nm209	25' x 25' (7.62 x 7.62)	4 artifacts	Hornum et al 2005:114
36Nm263	19.7' x 26.2' (6.0 x 7.98)	10 artifact	Hornum et al 2005:123
36Nm266	24.6' x 24.6' (7.50 x 7.50)	2 artifacts	Hornum et al 2005:132
SUBi-2673 Delaware Co. NY	28.6'x 28.6' (76m²)	58 artifacts	Kudrle 2011:7, 52
Herrick Hollow III Delaware Co. NY	45.8' x 45.8' (195m²)	Triangular biface base, 9 chert flakes	Hohman and Versaggi 2003:iii, 39, 51-52, 107
Herrick Hollow IV Delaware Co. NY	19.68' x 19.68' (36m²)	Middle/Late Woodland, tools, flakes, pottery	Hohman and Versaggi 2003:iv, 53-54, 65, 108; Hohman et al 2005:Table 131
Herrick Hollow V Delaware Co. NY	31.11' x 31.11' (90m²)	Levanna biface, 2 biface fragments, 11 sherds, 4 utilized flakes, 183 flakes	Hohman and Versaggi 2003:v-vi, 66, 81, 108
Herrick Hollow VI Delaware Co. NY	32.8' x 32.8' (100m²)	Levanna biface, 109 flakes	Hohman and Versaggi 2003:vi-vii, 82, 86, 90, 93, 95, 108
Herrick Hollow VII Delaware Co. NY	14.66' x 14.66' (20m²)	Late Archaic-Early Woodland, hearth, 3 tools, 7 flakes	Carroll et al 2007: Table 30; Hohman and Versaggi 2003:vii-viii, 96, 101, 106, 109
Tom Lloyd Sullivan Co. NY	44.31' x 44.31' (13.5 x 13.5)	lithic scatter	Lloyd and Heaton 2005:35
Park Creek I Broome Co. NY	22.24' x 22.24' (46m²)	3 Snook Kill/Genesee, bifaces, flakes, hearth feature, 1950+/-90 BP	Miroff 2002:i, 5, 30, 41, 86 Table4
Park Creek II Broome Co. NY	26.01' x 21.01' (63m²)	Late Archaic & Late Woodland bifaces, tools, flakes, hearth features	Miroff 2002:ii, 157
Raish Broome Co. NY	19.94' x 19.94' (37m²)	Corner notched biface, tools, flakes, Middle & Late Woodland C14 dates	Miroff 2002:iii, 31, 160

1988:687-688) concluded that, all things being equal, a staggered hexagonal grid - one in which the spacing between each test is equal, but staggered - decreases the space that exists between tests and therefore is more likely to identify archaeological deposits. The Krakker et al model assumes that artifact deposits are circular, that all sites have uniform artifact densities, and that all types of subsurface tests (auger, shovel test, test unit) have an equal chance of finding a site. Kintigh (1988) builds upon this work asking how the variables of test unit type, survey pattern and size, site size, and site artifact density influence subsurface site discovery. Using a Monte-Carlo program that allows manipulation of these variables over many repetitions, he examined their interrelationship and impact on survey results. In the end, in order to find all sites with a diameter of five meters and with a density of one artifact per square meter, subsurface tests would need to be excavated every 4.3 meters. Otherwise the likelihood that such sites go undetected is very high. Banning et al (2017:471-472) present a more recent summary of the issue.

The time and cost of implementing this theoretical strategy in large survey areas seems impractical (Kintigh 1988:708). But are we hampering our ability and mandate to find significant sites when we employ methods that inevitably lead to an unknown number of small archaeological deposits being missed during survey? In a Pennsylvania survey Petyk et al (2010:320) found the testing interval of 50 feet (roughly15 meters) inadequate for locating small pre-contact sites in upland locations, and wondered if the use of smaller intervals would result in the discovery of more National Register-eligible sites.

An Upper Delaware case from Monroe County, Pennsylvania highlights the potential danger of standard testing protocols. During survey a few artifacts were found in a single shovel test along a transect where tests were spaced every 50 feet (roughly 15 meters). Additional tests placed at decreasing distances from the original find did not produce artifacts. Only when tests were situated within a few meters of the original find were additional artifacts recovered, in some cases in great numbers (Blomster and Perazio 1999; Perazio 2005:308-309). Another Monroe County project more dramatically points out how abandoning preconceived notions about lithic scatters can have benefits. A thin scatter of artifacts from plowzone contexts, equaling approximately 16 artifacts per acre, was defined on the basis of shovel test transects. Subsequent stripping of the plowzone revealed “the remains of the only known prehistoric structure not situated in riverine setting” (Perazio 2005:309). Also found was a pit feature with carbonized plant remains and material for radiocarbon dating (Perazio 2005:309; Rinehart and Perazio 2001).

These examples are not unique in the study area. In an early survey of an area near Oxford, Warren County, a few artifacts were found but not recorded as a site. Later field work by a different investigator examined the same area and defined a more substantial plowzone site (Lore 2012a, b). During the investigation of upland sites in Monroe County, the size of sites discovered during Phase I survey was consistently revised upwards as a result of Phase II investigations (Walker et al 2007:Chapter 8). Similar examples can be cited from throughout the Northeast (e.g., Binzen 2008; Blakemore et al 2008; Versaggi and Hohman 2008). In a New York study of what were originally identified as 10 lithic scatters, the yield of artifacts from testing a locality with shovel test pits every 5 meters was nearly four-fold that of what was obtained using intervals of 15 meters (Versaggi and Hohman 2008:177). “What is clear is that we cannot adequately assess the significance of this class of site if we persist in tossing aside low densities of lithics found during reconnaissance" (Versaggi and Hohman 2008:178). Can small sites be considered significant on their own, or as a collective cultural resource?

The issue of significance remains a ticklish one in the management of cultural resources (cf. Butler 1987; Darvill 1995; Darvill and Little 2005; Leone and Potter 1992; Lipe 1984; Little et al 2000; Schaafsma 1989). Determining the significance of a resource requires the existence of some type of standard against which it can be judged. It is ascribed. It comes from the "outside" and is subject to the concerns of the moment be they academic, scholarly, social, political, or economic.

> Overlooking the significance of small sites may skew our understanding of past lifeways as those sites not only receive less research attention, but also are destroyed without being recorded thoroughly because they are "written off" as ineligible for listing in the National Register. Such losses point up the need to continuously reexamine historic contexts and allow new discoveries to challenge our ideas about the past. (Little et al 2000:21).

Custer (1983b, 1987, 1988) addresses the debate over the importance of lithic scatters, the quintessential small site of the region. They have the potential to contribute to a variety of important research issues such as lithic and other resource procurement, understanding the Late Archaic and later increase in small sites in interior and upland settings, and their relationship with base camps situated in riverine areas. In the Piedmont Uplands of Pennsylvania Custer and Wallace (1982:151, 154, 158,-159) note the small size (less than 10 meters in diameter) and low density of artifacts (20-25 or fewer) associated with Paleo Indian, Early Archaic, and Middle Archaic sites in comparison with the substantially larger and denser localities of the Late Archaic through Late Woodland periods. Given the relatively low numbers of Paleoindian through Middle Archaic sites in regional databases even small, plowzone-related localities are important for understanding settlement patterns.

Perazio (2005, 2008) is equally passionate about the importance of lithic scatters and the preconceived notions about them that lead to premature determinations of their research potential (also see chapters in Rieth 2008). We need to be asking what is the larger cultural context in which such sites existed, what are the research questions relevant to that context, and what data are needed to address them (Perazio 2005:309-310; Versaggi and Hohman 2008:175). As related in Chapter III small sites contributed to distinguishing differences between Archaic and Woodland period use of upland areas in the Poconos (Perazio 2008).

"Settlement pattern studies are based on the analysis of patterns and not individual sites" (Carr 2008:188). The numbers and densities of small sites or lithic scatters could reveal trends in the importance of upland settings and the resources to which they provide access. "When surveying small project areas where one or two lithic scatters are found, can we justify assessing their research potential as low when a larger project area might contain several more sites clustered around unique landforms" (Hohman and Versaggi 2008:179)?

Small sites should be considered important because they often represent single occupations and evidence of activities more difficult to segregate at larger, multicomponent localities (Binzen 2008:39; Curtin et al 2008:42). In particular, expedient or informal lithic technologies may best be defined in the context of lithic scatters (Grills 2008). Site 28SX432 is a good example. As a result of shovel testing at intervals of 10 feet and the excavation of two units, 10 artifacts were found distributed over a linear area of approximately 30'x15' (Kratzer 2007:41, Figure 17). Late stage bifacial maintenance and the expedient use of pebble sources of local chert is indicated by the artifacts. If an upland lithic scatter includes a chronologically diagnostic artifact and is situated within a poorly documented watershed in Pennsylvania it may be considered eligible for inclusion in the National Register of Historic Places under Criterion D (Carr 2002; Carr and Keller 1998; Miller 2001a). However, when evaluated in a broader context, the age of lithic scatters without diagnostic artifacts or datable material could be estimated (see below).

It has been suggested that many small sites likely represent functionally diverse, daily forays from residential bases or camps. Linking small sites with residential ones remains a hypothesis to be tested more broadly, with important implications for predictive modeling and determinations of site significance. Attractive settings within the foraging radius of a documented residential site may be more likely to contain archaeological deposits than similar settings elsewhere, especially if attractive settings are numerous and widespread in the broader environment. Alternatively, with the known distribution of small sites in hand we may better be able to predict the locations of camps or residential bases. As a group, small sites could be significant in defining the catchment area related to a residential base and reveal the myriad functional activities used in its support. In turn, the age of small sites or lithic scatters that lack diagnostic artifacts or contexts for establishing a deposit's age might be inferred from the age (or ages) associated with deposits at the residential base.

Does the size of foraging radii change through time as revealed by the spatial distribution and density of small sites? Does the density of small sites arguably linked with a residential base or camp reflect the size of the resident group, or the longevity of its occupation? Given what we presume about Native American mobility patterns through time, Paleoindian and Early Archaic camps would predictably have fewer foray sites associated with them. We then would expect to see the frequency and density of small sites increase through time, paralleling trends in the stability of residential bases and/or the size of resident groups. From this perspective, research focused on small sites becomes a test of overarching settlement patterns and how they may have changed through time.

Depending upon the setting of focal habitation sites, catchment areas or foraging radii could be markedly linear or amorphous in shape, or combinations of both. For example:

> Linear Foraging/Catchment Area: habitation site has a riverine or high order stream setting; watercraft may or may not be in use; exploitative tasks are focused on riverine or wetland related resources; and
>
> Amorphous Foraging/Catchment Area: forays radiate out in all directions and into a variety of habitats surrounding a habitation site.

The season during which a residential base is occupied, and the length of an occupation, could impact the nature of the foraging radius or catchment area since resources of potential interest might vary by season.

During the Late Woodland period, or by the time that native peoples become heavily invested in the gardening and farming of wild and domesticated plant foods in the context of high order stream/riverine settlements, foraging radii might be more linear in configuration than during earlier times. Farming-oriented settlements of the Upper Delaware are best characterized as "hamlets" or "dispersed villages". These are not settlements of clustered dwellings organized on a precise spatial plan. Instead, Delaware Valley settlements consist of few dwellings associated with storage pits, and surrounded by what are presumed to be cultivated fields or gardens. The contemporaneous dwellings and fields of neighbors would be at a distance.

It has been estimated that a planted field an acre in size could produce enough maize (40 bushels) to feed 5 people for a year (Thomas 1976:12-13 citing the 17th century observations made by Roger Williams of the Narragansett). Extrapolating this to the Upper Delaware Valley, and assuming that one to two acre fields are associated with each household, contemporaneous residential structures in a multi-family community dispersed across the valley floor could be spaced 500 feet (152 meters) or more apart. If a few residential structures instead were grouped and surrounded by cultivated fields, the distance between residential clusters would be even greater. In such cases, foraging radii associated with individual homesteads would overlap. Thus the foraging radii of farmers would need to be linear in configuration, extending into upland areas, or onto opposite sides of the river, assuming that no contemporaneous community existed there.

In order for the analysis of the relationship between lithic scatters and habitation sites to work it is important to know whether there are multiple habitations sites or camps with overlapping foraging radii and similar occupational histories. Attempts to connect lithic scatters to habitation sites also should consider:

-the relative proximity of sites taking into account available data dealing with the size and configuration of foraging zones or catchment areas that can be associated with residential sites;

-common diagnostic artifacts associated with the sites;

-geomorphic implications for the potential age of surface/plowzone deposits where lithic scatters occur; and

-lithic material utilization patterns of camps/residential bases and lithic scatters presuming that they should be similar except in cases where the latter relate to the procurement of toolstone.

B. Survey Goals, Field Methods, Site Size and Significance - Recommendations

Depending on the layout of transects of shovel test pits it is feasible that many small sites could go undetected. Transects of shovel tests or small excavation units should be unaligned, cutting down on the size of untested areas. A sample of high, medium and low probability zones within a project area need to be tested with shovel test pits and transects at less than 50 feet or 15 meters in order to increase the potential for discovering small sites. Minimally, high probability landscapes should be tested using smaller intervals between tests. For comparative examples from other states see Banning et al (2017:Table 1). Testing around an isolated shovel test pit that produces artifacts should begin with additional tests adjacent to the original and move outwards at intervals of 5 meters or less. Sweep widths where surface survey is employed need to be explicitly addressed and rationalized depending upon surface conditions and the nature of deposits that might occur (e.g., Banning et al 2011, 2017:476-477). The evaluation of a predictive model at the conclusion of a survey must address the degree to which small sites are accounted for.

"Archaeologists should explore a broader use of the thematic or multiple properties district concept when addressing the significance of small sites" (Versaggi and Hohman 2008:179). Under National Register Criterion D (United States Department of Interior, National Park Service 1997:21) a site could be considered as significant if it possesses characteristics that make it possible to:

> Test a hypothesis or hypotheses about events, groups, or processes in the past that bear on important research questions in the social or natural sciences or the humanities; or
>
> Corroborate or amplify currently available information suggesting that a hypothesis is either true or false; or
>
> Reconstruct the sequence of archeological cultures for the purpose of identifying and explaining continuities and discontinuities in the archeological record for a particular area.

As discussed above, small sites and lithic scatters, have the potential to address a number of research issues in addition to enhancing the effectiveness of predictive models. But this potential cannot be realized without systematic discovery and mapping which will require changes in currently adopted testing standards.

In many states the historic preservation office requests that areas that have not been surveyed in the last 10-20 years be re-surveyed. This is an acknowledgment that: single observations are often insufficient to characterize the nature of a surface or plowzone deposit; some previously used subsurface testing protocols were insufficient; the quality of previous efforts cannot be assessed (Altschul 2016; Banning et al 2017:474-476). Multiple surface surveys under different conditions are more likely to recover diagnostic artifacts given that only a fraction of a deposit's artifacts are likely to be exposed as a result of a single episode of cultivation and surface collection (Shott 2017:132). For example, Schrabisch's early collector interviews and surface surveys in the Upper Delaware Valley are useful but are known to fall short. In speaking of the areas adjacent to the mouth of Conashaugh Creek (Pike County, PA) he observes that ”no mementos suggestive of Indian camps seem to have been found near this place” (Schrabisch 1930:144). Yet a later project documented substantial surface and subsurface deposits with features in this exact location (Messner et al 2006).

Resurvey of cultivated fields or landscapes with exposed surfaces may not always be possible during the course of a CRM or Phase I project. It should be considered as a standard part of a Phase II investigation minimally involving a sample of small sites or lithic scatters that were encountered during the initial survey. Where small sites or others with low densities of artifacts appear to be confined to plowzone contexts, stripping of the plowzone of such sites should be considered as a standard part of a Phase II investigation. Investigations by Perazio and colleagues have shown this practice can have startling results.

During Phase 1 survey the nature of an encountered site should be used to adjust the predictive model and testing strategies being used. For example, the discovery of a camp or something that might be considered as a habitation site would enhance the probability of outlying forays and lithic scatters to occur in suitable settings within a hypothetical foraging radius of the camp or residential base. In turn, clusters of lithic scatters could be used to narrow down settings in the area where a habitation site might be expected.

Increased interaction with artifact collectors and avocational archaeologists will enhance the data base and in some cases mitigate the bias that results from single views of sites during a CRM survey; collectors characteristically revisit locations and at different times of the year. Further, we need to “to confront and, for analytical purposes, account for the effects of private collection” on sites whether or not they have been recorded previously or are newly discovered (Shott 2017:126). It is daunting to read Schrabisch’s accounts of his work in the Upper Delaware in which he laments “that ancient Indian fields have been denuded of their best treasures” (1915:7), or that former village and camp sites “have become all but depleted of their treasures so that fresh finds are made only occasionally” (1930:136).

Compliance reports rarely provide a clear justification for the depth below surface that excavations are taken in relation to the potential age of soils or deposits reflected in the descriptions found in published soil surveys. A compendium of the soil series associated with sites of known age possessing subsurface expressions would be useful in the initial planning of field strategies. Testing in the meander plains of low order streams can be confounding in that lateral deposits are often the rule rather than the extensive and more uniform overbank deposits associated with higher order streams. In meander plains the stratigraphy and age of deposits can vary dramatically over short horizontal distances.

We need to take to heart the fact that native peoples may have been in the Middle Atlantic Region in excess of 13,000 years. In western Pennsylvania (Adovasio et al 1990; Carr and Adovasio 2002), the DelMarVa Peninsula (Lowery 2009, 2015; Lowery et al 2012), and coastal Virginia (McAvoy and McAvoy 1997) Pre-Clovis artifacts have been recovered from what appear to be secure and dated deposits. No such deposits have yet to be identified in the Upper Delaware Valley but future site survey and testing programs should tailor field strategies to take their possible existence into account. It has been argued that evidence of Pre-Clovis occupations is widespread across the Americas (e.g., Halligan et al 2016).

Searching for Pre-Clovis and other Paleoindian occupations must consider the glacial history of an area. The Younger Dryas likely resulted in an erosional disconformity in alluvial sequences along major rivers throughout eastern North America, with renewed aggression of rivers adding to the potential destruction of previously intact Paleoindian sites in low terrace settings (Thieme 2003:165; Vento et al, in press). Add to this the fact that settlement patterns of Pre-Clovis cultures are not well known. Therefore targeting landscapes that might possess subsurface deposits of appropriate Pre-Clovis age would be more effective than a modification of predictive models to accommodate speculation about relevant settlement patterns.

Field walkovers prior to formal surveying are recommended to detect small landscapes and other features that could result in the revision of sensitivity areas in the modeling effort (e.g., NJDEP/HPO 2018) . Some springs, first order and intermittent streams, and small landscapes adjacent to wetlands may not be visible at the scale of 7.5' USGS quadrangles. Rock overhangs, primary and secondary sources of toolstone also might be located during preliminary walkovers. Rock overhangs in proximity to, or within the hypothetical foraging radius of a known camp or residential base arguably would have a good chance of containing cultural remains. The effectiveness of a pre-survey walkover on modeling will vary depending on the quality of environmental data accessed for modeling and the scales at which it has been mapped.

C. Revisiting Select Variables, Environmental and Cultural

1. Environmental

Distance to surface water is a key component of every model used to predict site locations. Older site records can pose problems, however, in effectively analyzing relevant data. There are problems using the New Jersey State Museum site files in terms of locations mapped on USGS 7.5' and other topographic maps to determine distance to surface water or stream confluences, particularly when sites recorded by Max Schrabisch in the early twentieth century are involved. Site areas shown on maps may indicate that a site is immediately adjacent to surface water whereas original field notes often provide contradictory information. In other cases site form data, and not just for localities recorded by Schrabisch, are sufficient to relocate a site generally and gain an understanding of its probable size, but distances to surface water are not recorded. The examples below illustrate disparities that are not inconsequential in the analysis of this variable and imply that map measurements are problematic when site forms or field notes do not provide specific details:

-28Wa6 map shows site adjacent to water, field notes say 200 yards (182.2 meters);
-28Wa20 map shows site adjacent to water, field notes say 80 feet (24.3 meters);
-28Wa119 map shows site adjacent to water, field notes say 1200 feet (365.7 yards);
-28Wa252 map shows site adjacent to water, field notes say 100 feet (30.4 meters);
-28Wa54 field notes indicates site is adjacent to water, map location dies not;
-28Wa248 map shows site adjacent to water, field notes say 200 yards (182.2 meters);
-28Wa622 map shows site adjacent to water, field notes say 25 feet (7.62 meters);

-28Sx47 map shows site adjacent to water, field notes say 15 feet (4.5 meters); and
-28Sx349 map shows site adjacent to water, field notes say 200 feet (60.9 meters).

Table 48 presents data for a sample of sites for which distances to surface water could be tracked with some confidence. A value of "0" is used in my analysis of site file data to represent localities that are immediately adjacent to some type of surface water. Narrative descriptions of a site as "near", "close", or "on the east/north/south/west bank of" a stream were not taken as unequivocal indications of immediate proximity. Terms such as "at the headwaters", "on the edge of", "fronting", or "on the shore of" were considered to mean immediate proximity and were assigned a distance value of "0". When a location on a map in a site file suggested immediate proximity and an accompanying narrative confirmed this in some way, it, too, was assigned a distance value of "0". Obviously distances to surface water recorded on site forms were employed. Locations shown on maps that suggested immediate proximity were not used in the analysis without additional supportive evidence. Measurements from site boundaries shown on 7.5' quadrangles to the nearest water source were not employed. I use distances to swamps, marshes, or wetlands if they represent the nearest source of surface water. Data regarding diagnostic artifacts, cultural components, or period affiliations were not recorded with sufficient frequency to allow for tracking how the relationship of sites with surface water may have changed through time.

TABLE 48
Distance of Sites to Nearest Water, Warren and Sussex Counties, New Jersey*

OBSERVATIONS	WARREN COUNTY	SUSSEX COUNTY
Sites in Analysis	118	90
Range (meters)	0 - 1609.3	0 - 914
Mean (meters)	99.8	103.3
Median (meters)	129.4	92.7
Trends	50% of sites are within 10 meters of water 75% of sites are within 92 meters of water 90% of sites are within 256 meters of water	50% of sites are within 52 meters of water 75% of sites are within 153 meters of water 90% of sites are within 305 meters of water

*Exclusive of Rockshelters

For both counties the large number of "0" values and extreme outliers impact the difference between the mean and median calculations of distance to surface water. If extreme outliers were dropped for Warren County sites the median distance would decrease to 100.7 meters and the mean distance to 63 meters. If "0" values added based solely on the mapped locations of sites the mean distance would decrease. For Sussex County sites, were extreme outliers excluded from the analysis the median distance would drop to 91.4 meters and the mean distance to 94.2 meters. Were "0" values added based solely on mapped locations, the mean distance to water would decrease.

Results of this analysis correspond in a general way with previous evaluations in pointing out differences that can occur depending on the scale of the geographic area being considered and the environmental diversity it may encompass. Previous considerations of site settings on both sides of the river (e.g., see Tables 24, 25, 28, 29, 31, 32, 33, 37) indicate that the greatest majority of sites are within 185-200 meters of water, although some sites can occur at distances up to 1207 meters from water. In comparison, the analysis reflected in Table 48 indicates that the greatest majority of sites are found within 305 meters of water, although a significant majority occur within 153 meters. Some sites can be found up to 1609 meters from some type of surface water. How important might such outliers be in bettering our understanding of settlement patterns and the use of what may be unique environmental settings? Means and medians of distances of sites from surface water show distinctive differences between New Jersey and Pennsylvania, and differences between subareas in each state. Table 48 shows what might be different patterns for New Jersey portions of the study area.

It is not possible to determine if and when topographic drainage patterns discernible on maps represented active intermittent or perennial first order streams. Assumptions about their viability could impact predictions about site locations in upland or interior areas. A better understanding of the impact of environmental changes on intermittent streams, first order streams, and springs would improve modeling efforts and might serve to reconcile our observations of the extreme distances that some sites are from existing sources of surface water.

Kvamme 1989:169, 180-181) points out that an environmental variable that seems to have predictive value must be evaluated in terms of how that variable is represented on landscapes throughout a study area. This point has been raised repeatedly in the current report. One could hypothesize that there are geographic areas where the drainage net is so dense that distance to surface water would cease to be an effective predictive variable if not considered in conjunction with other variable; the distance from water of non-site locations could be the same for sites. As seen in Figure 7, the density of streams and wetlands per unit area appears to be greater in the northern half of Warren County, New Jersey than in its southern portions (Carson and White 1998). Areas in Sussex County seem to be more well-watered than those in Warren County (Figure 8). More significant variation likely would be seen if the drainage nets (streams per unit area) of basins within the counties were calculated.

Distance to stream confluences does not seem to be important for predicting the specific locations of sites. However, such settings are arguably important for characterizing the economic or resource potential of a broader area to the degree that they represent ecotones, zones of habitat overlap, or natural concentrations of floral and faunal resources. Within such an area then, other variables may be more predictively powerful in specifying site locations than areas lacking stream confluences.

In reviewing maps of the Upper Delaware Valley one is struck by the extensive and widespread distribution of upland swamps, and natural ponds and lakes, especially on the Pocono Plateau. Some ponds in portions of Delaware County, New York Province (East and West Branches of the Delaware River) have been formed from pre-existing wetlands over the past century by beaver activity (Hohman and Versaggi 2003:4). Some of the best known sites in Schrabisch's (1917:13) opinion are adjacent to swamps or lakes in Warren and Hunterdon counties; their important association with sites throughout the Upper Delaware has been noted in previous discussions. Thieme (2003:167) maintains that the identification of relict freshwater marshes and floodplain settings within proglacial lake basins is crucial to finding stratified prehistoric sites.

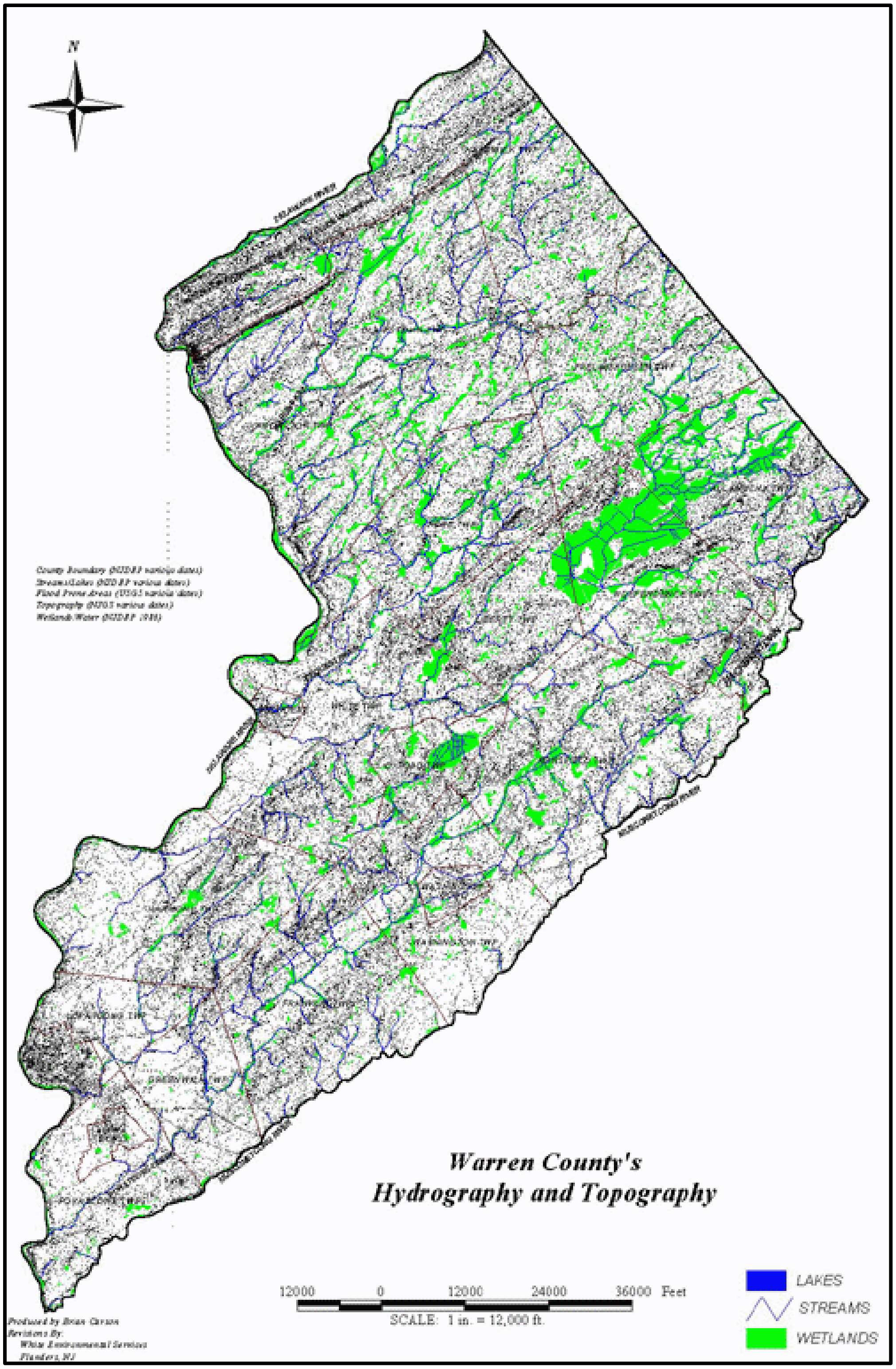

FIGURE 7. Hydrography and Topography of Warren County, New Jersey. Source: Carson and White 1998 http://www.co.warren.nj.us/environment/maps/hydro8x10.gif

FIGURE 8. Variation in the hydrography of two areas of roughly equal size in Warren and Sussex counties, New Jersey. Source: USGS National Hydrography Dataset, Medium Resolution for New Jersey https://www.sciencebase.gov/catalog/item/imap/581d75d5e4b0dee4cc8e5f29

The scale of USGS 7.5' quadrangles may be insufficient for identifying all such features (e.g., Hasenstab 1991) requiring the use of additional sources of information, including unique soil series, soil survey maps and aerial photos. For example, in Pike County the Paupack series is indicative of swamps and bogs, the Freetown series of post-glacial swamps and bogs, and the Gleneyere series of the alluvial flats of old lake beds (Craul 1995:35-36, 44).

Floodplain and terrace settings appear to be a clear preference for sites of varying types and ages. The close proximity of attractive floodplain and terrace settings to valley walls and steep uplands would make it relatively easy for lowland inhabitants to access a variety of plant and animal resources. This would include substantial sources of firewood, especially if the amount of tree blowdowns seen in modern times can serve as an analogy. Sources of firewood rarely are figured into predictive models and settlement pattern studies (for an exception see Jochim 1976).

The 18th century American Indian community of Pachgatoch in western Connecticut included two components – summer huts and winter huts - situated about 6 miles from one another. Access to firewood was a primary concern in the location of the winter huts where a sledge path from the adjacent uplands was created to facilitate the movement of wood supplies (Dally-Starna and Starna 2004:6-7). There is a large literature on deadwood and forest ecology and management that could be mined for correlations of this resource with forest and landscape types, and feasibly used as a variable in assessing an environment's overall resource potential in a modeling effort.

Are locations where interior and upland landscapes are in close proximity more likely to attract settlements in floodplain/terrace settings than those in wider valleys, i.e., where vertical zonation does not occur over relatively short distances? The proximity of environmental zones represented by the former would conform to the conclusions of some modelers who stress the importance of ecotones, zones of habitat overlap, vertical zonation , and environmental diversity in general (e.g., Custer et al 1986; Dekin et al 1983; Eveleigh 1984b; Gardner 1978, 1987; Hasenstab 1983, 1984; Kuznar 1984a, b; Kvamme 1985:219). The power of variables generally associated with site locations might therefore be increased in project areas where environmental zones and vertical zonation are encountered over relatively short distances from floodplain and terrace settings.

Early-on Schrabisch (1917:24) attributed the density of sites in the Flemington, New Jersey area to the occurrence of argillite outcroppings. Many quarries likely represented common ground for native people. Predictably the density of sites, and therefore the frequency with which the typical environmental settings associated with sites actually produce sites, should increase with a foraging radius of a substantial source of toolstone. But the general lack of focus on quarries in predictive models is something that needs to be corrected (LaPorta et al (2000), although exceptions can be noted (e.g., Riegel et al 1994). Recent survey work in the Musconetcong Valley of New Jersey on the southern end of the project area included an analysis of the composition of area bedrock, ultimately identifying sources of chert and jasper and associated sites. Yet previous research in the area failed to do so as part of evaluating the sensitivity of areas to contain archaeological sites (Tomaso and Eshelman (2014:2-25, 2015).

A review of Pennsylvania and New Jersey site files, CRM reports, archaeological and geological literature and maps provides substantial background on known sources of toolstone and the formations with which they are associated (Table 49). This provides background for investigators modeling important variables for project areas where lithic resources used in chipped stone technologies have yet to be identified.

TABLE 49
Examples of Toolstone Sources in the Upper Delaware Valley

Material	Formations +	Comments	References
cherts	Allentown, Buttermilk Falls, Coeymans, Epler (Big Springs, Branchville members), Esopus, Franklin Marble, Glenerie, Kalkberg, Leithsville (Califon, Hamburg, Wallkill members), Limeport, Helderberg, New Scotland (Flatbrookville, Maskenozah members), Manlius, Ontelaunee (Beaver Run, Harmonyvale members), Oriskany, Rickenbach (Hope member, Crooked Swamp facies), Ridgely Sandstone, Shawangunk (Minsi member), Stonehenge, Tuscarora	see summaries in Carr 2016; LaPorta 1989, 1990, 1994a, b, 1996, 2009; LaPorta and Associates 1998, 2009; Pretola and Freedman 2009 ; Vento 2007, 2016; Wall and Botwick 1995:10-11; can occur in nodular and bedded forms and as gravel in secondary deposits in river floodplain and terrace deposits; the Washington soil series formed in glacial till that can contain chert gravel (Fletcher 1979:80)	Bayley 1941:68, 86-87; Bergman et al 1996:62, 65; Cook et al 2002:7-4; Drake 1969; Epstein 1989, 2006; Hornum et al 2009:48, 59; Hunter et al 1985:5-3; Kelly et al 2012; Kraft 1985:46; LaPorta 1986, 1994:59, 131, 1996:19-27, 31-32, 35, 40, 42-43; Lavin 1983; Lavin, Lavin and Prothero 1981; Lothrop, LaPorta et al 2018:298, 304; Miller 1939:42, Figure 21; Patterson 2009; Pevarnik and Blondino 2010:Table 1; Pretola and Freedman 2009:180, 187, Figure A58; Schrabisch 1915:56, 1917:46, 66, 68; Schuldenrein 2008; Stinchcomb et al 2009; Tomaso and Eshelman 2014:2-4, 2015:2-20; Walker et al 2007:8-31; Willard 1938:13-14, 16, 30, 33, Figure 8; Wolfe 1977:47, 55-56
"flint"	Onondaga limestone	We visited Devil's Island, a limestone promontory on the margins of the great Paulinskill Meadows behind Newton, tracing a vein of flint along the ridge crest to an isolated vantage point (Wright 2009:ii)	Marchiando 1966:3
jasper	Hardyston	See summary in LaPorta 1994	Aaron 1969; Bayley 1940, 1941:2, 8-9, 21, 32; Kardas and Larrabee 1980; LaPorta 1994:132, 1996:18-19, 39, 45-58; LaPorta and Associates 1999:Table 1, 2009:21; Lavin and Prothero 1987; Miller 1939:45, Figure 24; Myers 1934; Tomaso and Eshelman 2014, 2015:5-14
quartzite	Hardyston, Shawangunk	at the base of the Shawangunk Formation at the boundary with the Ramseyburg member is found pebbles of quartz, quartzite and chert up to five inches long (Epstein 2006)	Aaron 1969; Bayley 1940; Tomaso and Eshelman 2015:5-14
argillite, argillaceous siltstones	Ontelaunee (Pen Argyl Grit, High Point member), Poxono Island, Shawangunk	much of this may not be workable	LaPorta 1996:28, 31; Lavin 1983; Schrabisch 1915:26; Wolfe 1977:49, Table 2.2

Specific quarries may have loomed large in Native American worldviews and settlement movements increasing the likelihood of encountering sites associated with them, or found in a foraging radius focused upon them. Singular historical moments that significantly alter the trajectories of societies are one focus of what has been called an event-centered archaeology (Gilmore and O'Donoughue 2015). This perspective asks us to think about how the initial discovery of a useful material source conditioned peoples use or perceptions of a particular landscape through time, and the degree to which they later sought out, and repeatedly used, other sources of the same material. Can the use history of individual quarries be used to document the process of how a people "learned" a broad landscape, or developed and refined an ethno-science of the conditions under which a material might be found?

The well-known jasper quarries of eastern Pennsylvania, and the under-studied ones of New Jersey, are along what could be construed as a natural travel route that is associated with a distinctive line of hills, and ultimately links with a ridge and valley system connecting the area with the greater Northeast (Figure 9). The same can be said of a number of chert quarries in the Upper Delaware Valley project area.

FIGURE 9. Ridge and Valley and Highlands natural corridors linking the Delaware and Hudson river valleys. A. Allentown, Pennsylvania; B. Phillipsburg, New Jersey; C. Delaware Water Gap, Pennsylvania; D. Sussex, New Jersey; E. Kingston, New York. The Kingston, New York area is well known for sources and quarries of Normanskill chert. Source: Mapper Acme 2.1 and Google Maps.

The concept that the use of quarries is embedded (*sensu* Binford 1979) in settlement movements, rather than a hub around which movements are organized, is well established in the regional literature. We need to be more explicit about how embeddedness applies to settlement patterns through time; it can impact the predictive value of material sources in models. The chert quarries near Marshalls Creek, Monroe County, Pennsylvania are a case in point.

In the Marshalls Creek area a series of quarries (n=10) are situated in an upland about 6 kilometers from floodplain and terrace settings along the Delaware River (Baublitz, Harral and Basalik 1995; Baublitz, Harral, Lewis and Basalik 1995; Stinchcomb et al 2009). The toolstone at each quarry is mediocre, at best. There is minimal evidence of the quarries being used prior to the Late Archaic period. Their most intensive use takes place during Woodland times, especially the Late Woodland. The Marshalls Creek lithic catchment area is defined by a 1.6 km (one mile) radius around the quarries – based on the analysis of 65 sites in the Marshalls Creek study area which had 50% or more of local cherts in their assemblages (Stinchcomb et al 2009). The most intensive use of the quarries corresponds with the time when semi-sedentary to sedentary settlements are well known in settings adjacent to the river.

Attention afforded these quarries during this time arguably resulted from: their location within a foraging radius related to an established base camp along the river; the heightened economic interest in plants and forest resources; and the fact that quarry use could be combined with other economic pursuits in the same upland environments. This corresponds with what Timothy Ingold (2000:195) has called a taskscape - the interlocking of the multiple tasks that people undertake in any given environment as part of their normal day. In other words, no single task motivates the use of a landscape; it is the combination of tasks that does so. The one-time or sporadic use of lithic sources that fail to stick out as "quarry sites" could be thought of in the same way, especially in areas where potential sources of toolstone are in the form of near surface regolith/float, or gravels that can be casually foraged. Ridge and Valley of portions of Pennsylvania and New Jersey in the Upper Delaware Valley are examples of such areas. The implication is that the predictive value of material sources in a modeling effort could vary depending upon the nature of a source (i.e., visibility, extraction methods required, size, quality of material) and its setting in the broader landscape.

The effect that sources of steatite and other materials of interest to native peoples had on the positioning of sites has not been explored to any degree in the Upper Delaware. For modeling purposes, sources of such materials would be important for scoring the resource potential or habitat suitably of survey tracts, if not in the prediction of more specific site locations. Potential sources of select materials are therefore worth noting.

Steatite sources occur in the Easton/Philipsburg area of Northampton and Warren counties (Bachor 2017:Table 2.3; Bayley 1941:6, 12, 34, 94-95; Geyer et al 1976:193-198; Gordon 1834:152; Greene 1995:100-102; Miller 1939:42, Figure 21; Schrabisch 1917:47). Kraft (1982:20) doesn't think that the Easton/Philipsburg source was ever exploited by the Indians. Bachor (2017:29-30) suggests that the fibrous asbestos component of the material may have made it problematic to carve causing it to be overlooked, as seems to have been the case with similar material elsewhere in the steatite belt of the eastern United States. Schrabisch (1917:47) mentions that steatite occurs at the northeastern slope of Jenny Jump Mountain in Warren

County. Geologically the association would be with the Franklin Marble, similar to the context of the occurrences in the Easton Philipsburg area.

Known sources of crystal include:

> -Crystal Hill immediately northwest of Stormville, Monroe County, PA (Brodhead 1870:77), associated with the Ridgeley through Coeymans formations, undivided of sandstones, siltstone, limestone and chert (Berg and Dodge 1981:Stroudsburg Quadrangle; USGS 2018a);
>
> -Kunkletown, Monroe County, PA (French 1968:Table 113), part of Chestnut Ridge and associated with the Mahantango Formation (Berg and Dodge 1981:Sheet 318, Kunkletown Quadrangle) of shale and sandstone (USGS Mineral Resources Online Spatial Data 2018b); and
>
> -Wind Gap, Monroe County, PA (Donald Kline, 2014 personal communication) , part of the Blue Mountain and associated with the Shawangunk Formation (Berg and Dodge 1981: Wind Gap Quadrangle) consisting of fine- to very coarse grained sandstone (USGS Mineral Resources Online Spatial Data 2018c).

Elsewhere in the Delaware Basin quartz crystals have been linked with the Pocono Sandstone (Geyer et al 1976:59; Inners 1998).

Possible sources of ochre occur in Sussex and Warren counties, New Jersey where it was mined historically (Hunter et al 2001; New Jersey State Centennial Board 1877: 287-289). The principal ochre/ocher belt in eastern Pennsylvania is a comparatively narrow strip extending from Reading to Allentown in Lehigh County (Stoddard and Callen 1910:424). Of interest is its co-occurrence with clays that are plastic and vary in color from white to brown with red and purple hues also observed (Stoddard and Callen 1910:424). A number of these historically known ochre sources would fall within a foraging radius of the native sites on which ochre is found.

Boulanger et al (2017:Figure 1) map and discuss a variety of sources of mica of potential relevance to the study area. A formally mined source of mica is located in Warren County, New Jersey, west of the town of Harmony (Vermeule 1959:Sheet 24, 11-9, 12-7). Additional sources are noted in French (1968:Table 113), Geyer et al (1976), Holmes (1919:241-252), and Leasure and Shirley (1968).

Area clays would have been important to Transitional Archaic and later Woodland cultures for the production of pottery. While some major sources of clay can be noted in the project area (e.g., Mathews 1886:1039, 1229; Ries et al 1904:505, 507) others are widespread. For example, clays are associated with the Livingston series in Sussex County (Fletcher 1979). Most types of rock that could be employed as temper in pottery manufacture also are widely distributed. An exception is nepheline syenite. Kraft (1975:137) recognized the consistent use of nepheline syenite as a pottery aplastic in the Upper Delaware Valley for wares made throughout the Late Woodland period, and its occurrence as cached lumps in Late Woodland pit features. Its use may extend even earlier in time (Stewart et al 2015). Small outcrops occur northwest of Beemerville, New Jersey (USGS 2015) in interior portions of the Upper Delaware Valley, although Kraft (1975:137) notes its occurrence as gravel along the Delaware River and in glacially transported deposits. The Beemerville source may enhance the potential for archaeological sites in nearby areas.

A number of researchers have explored the degree to which some plant and forest types may be a fingerprint of past landscape management by native peoples. The use of fire is one of the most frequently cited techniques used by native peoples to modify the environment, although opinions are divided about the frequency and extent to which settings were burned over (cf. Abrams and Nowacki 2008; Buell et al 1954; Patterson and Sassaman 1988; Russell 1983). In particular, fire may have been employed to manage forests in which important mast and nut bearing trees occur. Speaking of the prehistory of plant use by the native peoples of the Eastern Woodlands Smith (1978:114) states that "of all the wild plants, nuts as a group were certainly the most important food. They are more abundant than any grains or fruits, are easier to harvest, and contain more calories and protein per gram of food". Of the mast species represented in the Upper Delaware and broader region, butternut and black walnut have the greatest nutritional value in terms of calories, protein and fat, while acorns and chestnut are outstanding sources of carbohydrates (Messner 2011:Table 2.1; Scarry 2003:64, Table 3.3).

Given the use of nuts throughout prehistory in the Eastern Woodlands and the Upper Delaware (Stewart 2018:Table 27) it is reasonable to ask if arboriculture or silviculture was practiced (Cowan 1985:218). On the basis of macro-regional studies in the Eastern Woodlands (Abrams and Nowacki 2008) the answer to the question would be, yes. Following Abrams and Nowacki (2008:1133):

> Climate does *not* (emphasis in original) stand alone as the primary factor for the long-term perpetuation of mast trees in the eastern forest during the middle to late Holocene. One irrefutable fact is that the vast majority of oak, hickory and pine forests in the eastern USA will be replaced within one generation by later successional species, most notably maples and beech, in the absence of fire.

Following the work of Thomas-Van Gundy et al (2015) Truitt and Mellin (2017a, b) use concentrations of pyrophilic trees species (those that can tolerate fire) of economic importance to indicate zones where archaeological sites might occur in Delaware. Thomas-Van Gundy et al (2015) used witness tree survey data from the 18th and 19th centuries to calculate the percentage of fire resistant and fire phobic tree species across the northeastern United States. Mapped data suggests that pre-contact Native Americans are responsible for concentrations of high percentages of pyrophilic species in some geographic areas.

Using select plant and tree species to indicate areas of repeated Native American landscape management has obvious potential for assessing the potential for archaeological sites to exist in an area, at least for sites dating to late pre-contact times. Historical records seem to make clear that the vegetation in some portions of the current study area was impacted by Native American practices. The Musconetcong Valley of New Jersey was thinly wooded historically and attributed to the aboriginal use of fire. Large areas of the valley were characterized as open plain or “barrens” (Wacker 1968:28-31). In reference to the 18th century history of Paupack Township (Wayne County, PA) the understory of an oak woods was so thoroughly cleared by recent Indian burning "that a deer was visible as far as the eye could see" (Mathews 1886:701).

Recognizing vegetation patterns that are at odds with expectations stemming from an understanding of climate, landscape setting, the influence of wild fires, and the habitats and presumed natural ranges of particular species and their mutualist partners have been used to implicate or question the role of Native Americans in landscape modification and plant dispersal (e.g., Abrams and Nowacki 2008; Asch Sidell 2008:47-48; Fulton and Yansa 2016; Keener and Kuhns 1997; MacDougall 2003; Murphy 2001; Russell 1981; Trachtenberg et al 2008:136-137; Tulowiecki and Larsen 2015; Warren 2016). But investigating Native American landscape management must proceed with caution and recognize the broad and patchy geospatial scales that might be involved, as well as the fact that altered environments or niches may be the cumulative result of incremental changes over extended periods (Lightfoot et al 2013:290; Wagner 2003:129-130). Research efforts should therefore focus on micro-geographic areas that include one or more settlements with a long history or (re)occupation. It is critical that such investigations be interdisciplinary employing multiple lines of evidence.

2. Cultural

The potential impact of natural travel corridors on site frequencies and site types has been raised in previous discussions. Travel routes arguably relate to the distribution of Paleoindian sites in the project area and elsewhere (e.g., Lothrop et al 2017, 2018; Stewart and Rankin 2018). In New Jersey the most obvious of these are the basins of the Paulins Kill and Pequest rivers. These connect with the Wallkill basin which then provides access to the Hudson River watershed. Included is the black dirt area of New Jersey and New York representing a Holocene wetland that may have been an additional attraction for Paleoindian and later groups (Lothrop et al 2018:292). The northeast to southwest trending Shawangunk and Kittatinny mountains flank these basins on their north/northwestern side in New York and New Jersey, and are represented on the Pennsylvania side of the Delaware River by the Kittatinny and Blue mountains. Following the trend of the mountains in Pennsylvania would bring a traveler through the area of the well-known jasper quarries of the Reading Prong (see Figures 6, 9).

On the southern end of the study area the long valleys trending northeast-southwest through the New Jersey Highlands represent natural travel routes (Kraft and Mounier 1982a:58). Southern portions of the Highlands provide more open routes than northern sections of the Highlands (Fittipaldi 1980).

Indian trails of the colonial period, while they take advantage of aspects of topography, crosscut stream valleys and mountain/ridge systems (cf. Figures 10-12; for additional detail see Wallace 1993:44, 84, 101, 124, 128, 132-133, 157). In appearance they are more like the Tobler’s paths discussed above. Social networks undoubtedly had an impact on destinations and lines of travel. The complex history of native engagement with Europeans, especially the economics of trade, certainly impacted the movements of native peoples. The pre-contact antiquity of these trails cannot be presumed. One could speculate that increased densities of Late Woodland and Colonial/Contact period sites could occur in areas within a reasonable distance of the trails. The predictive power of environmental variables associated with site locations might also be enhanced in areas within a reasonable distance of the trails.

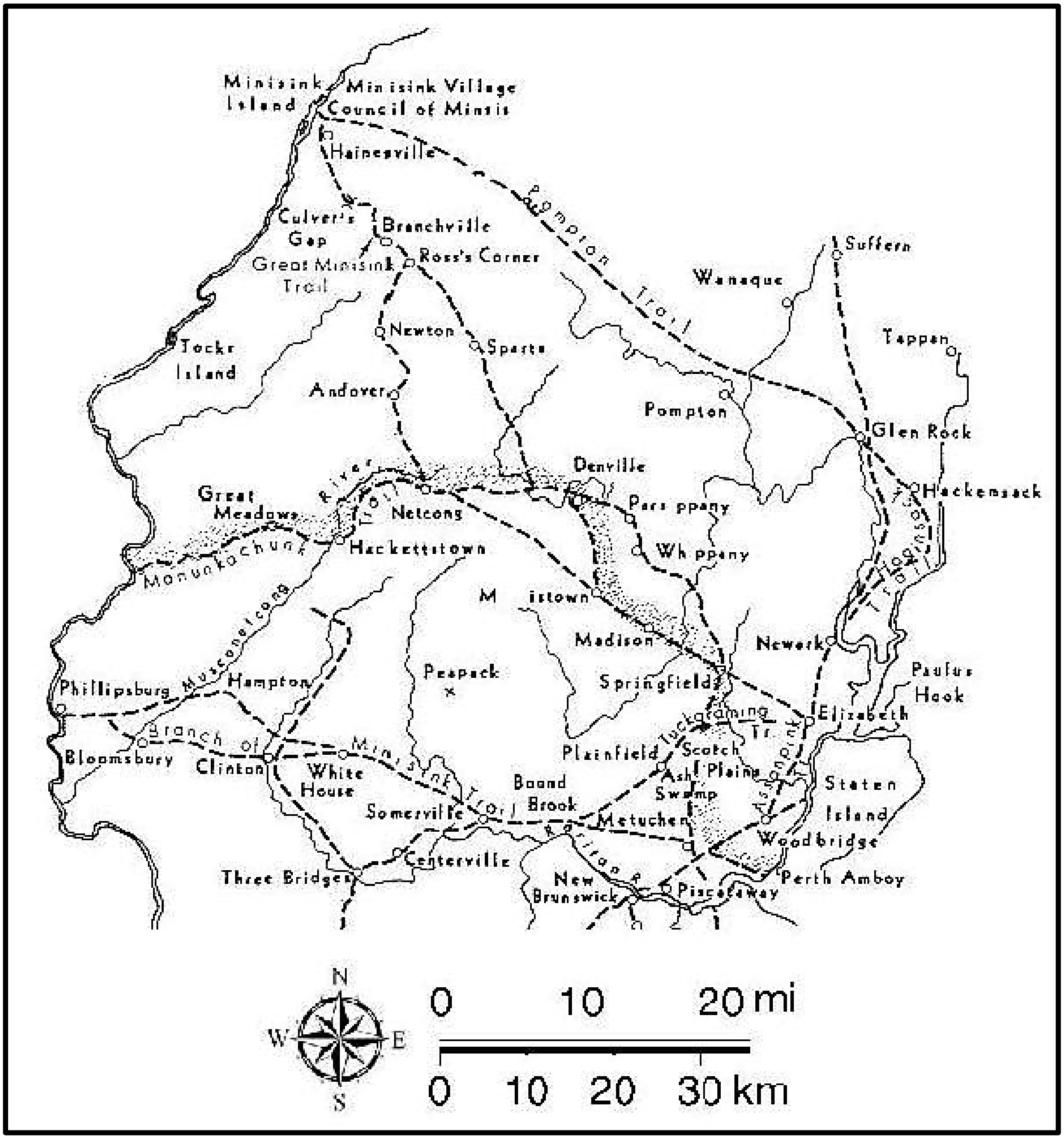

FIGURE 10. Conjectured major historic Indian trails of New Jersey relevant to the project area. Stippled area represents the position of the Wisconsin Terminal Moraine. Modified from Wacker 1975:Map 2.1 and Snyder 1973.

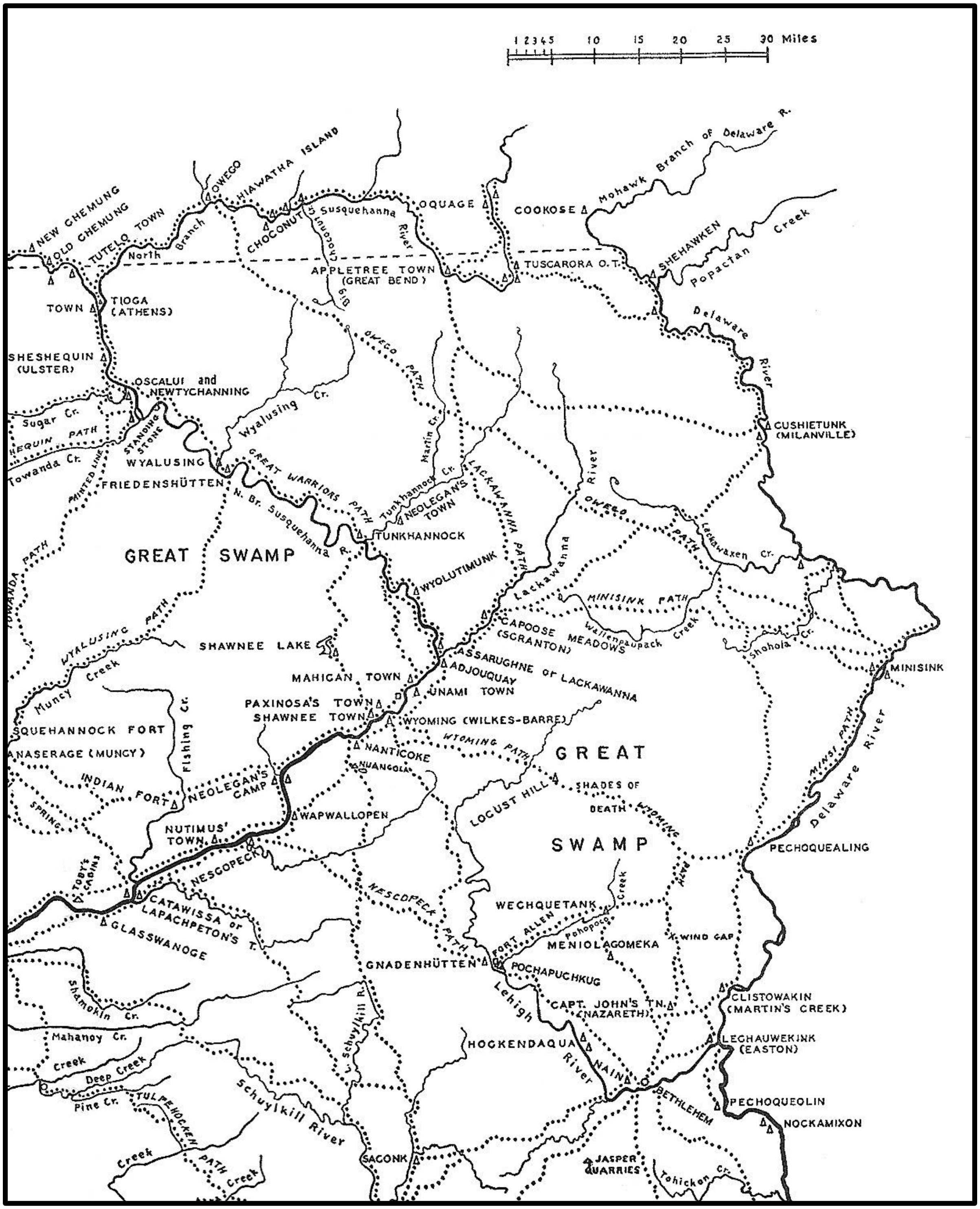

FIGURE 11. Historic Indian paths in Pennsylvania relevant to the project area. Modified from Wallace 1952.

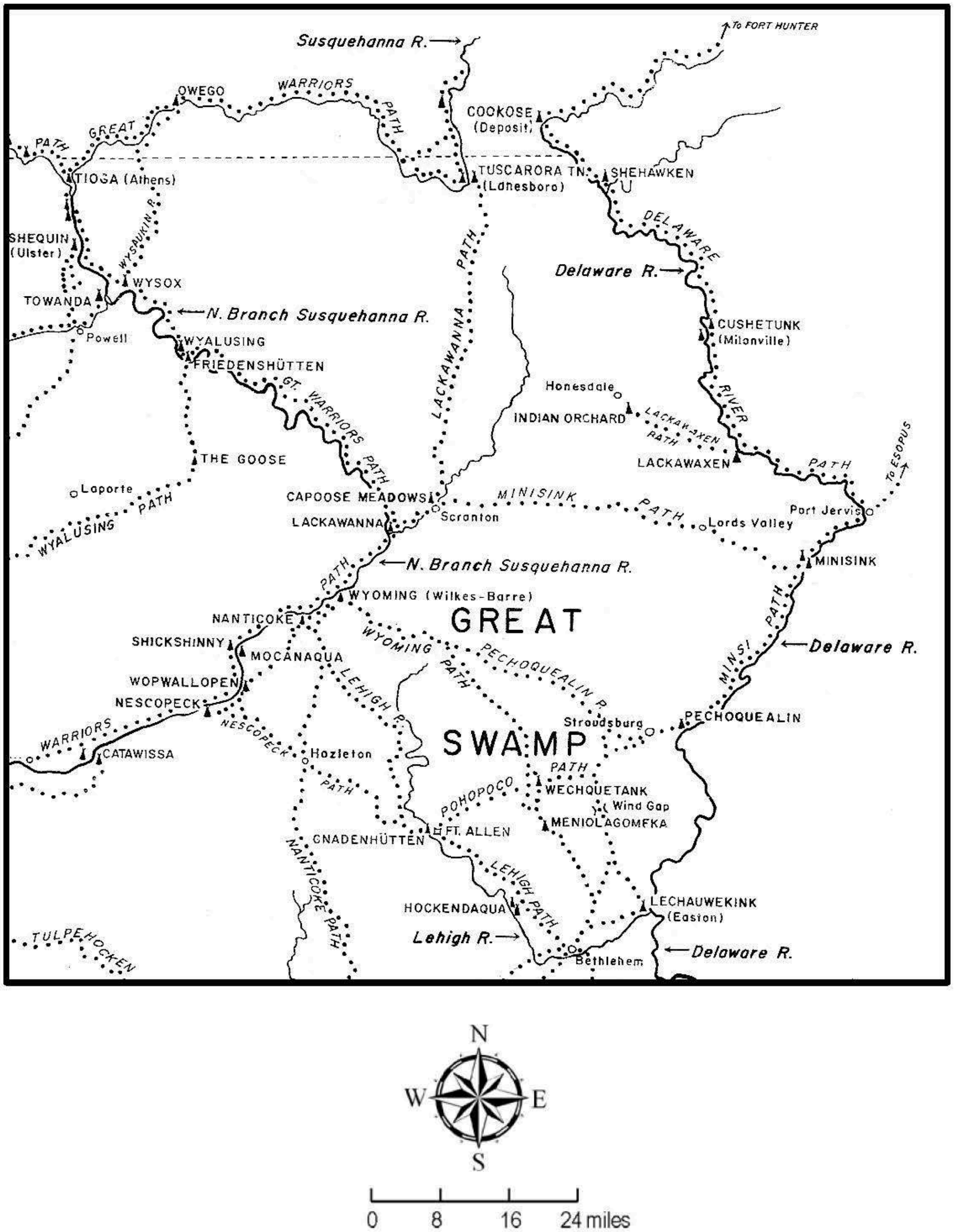

FIGURE 12. Historic Indian paths in Pennsylvania relevant to the project area. Note the lack of some trails shown inn Figure 11. Modified from Wallace 1993.

The recognition and reuse of "sacred space", or space made special by its association with human remains or mortuary features, is something that archaeologists have consistently attributed to native peoples (e.g., Stewart 2017). It is documented by such things as reuse of burial mounds over long periods of time, cemeteries, the intrusion of mortuary features into pre-existing ones, and the recycling of artifacts from mortuary caches. The reuse of localities surrounding sacred space might be anticipated, i.e., the predictive power of environmental variables associated with site locations might be enhanced within a foraging radius of places where burials, human remains, or mortuary features have been encountered.

Sounds associated with waterfalls, rapids, and relatively enclosed spaces like caves, topographic gorges, and cliff faces may serve to define sacred spaces of sorts. Their study is part of the phenomenological approach to landscape archaeology and the broadening of our understanding of how the people of the past experienced their world (Mills 2014; Primeau and Witt 2018; Taçon 1999). Nash (2016, 2017) suggests that a small number of Middle and Late Woodland sites near waterfalls in the Virginia Blue Ridge embody the symbolic character of waterfalls and their plunge pools. In occurring on steep, north-facing slopes they don't conform to the topographic parameters generally associated with sites in settlement models for the periods.

The Upper Delaware abounds with such places with a number of them (e.g., Buttermilk, Bushkill, Raymondskill, and Shohola falls) representing tourist destinations. Waterfalls and other unique "soundscapes" likely fall outside of settings considered by modelers in predicting site locations. Further, if such settings are symbolically important, then the predictive power of environmental variables associated with site locations elsewhere may be magnified in areas surrounding soundscapes.

In an analysis based primarily on historic documents, Becker (1983, 1988) argues that circa 1500-1740 AD the area known as the Forks of the Delaware was a buffer zone between the territories of the Lenape, Munsee, and Susquehannocks and contained no substantial settlements. The Forks encompass a large territory along the Lehigh and Delaware rivers (Becker 1983:Figure 1). " This area to the south and west of the water gap down to the junction of the Lehigh and Delaware rivers is now Northampton County, Pennsylvania" (Becker 1983:5). Such observations raise the possibility that open zones in which no substantial residential bases will be found might exist between the territories of pre-contact groups. I suspect that such zones would not preclude the existence of sites representing forays or the short term camps of groups travelling through the area.

The existence of territorial buffer zones will, of course, confound the use of predictive models to a degree. It is important for future research and modeling that large areas that have produced no, or only small sites as a result of systematic survey be clearly identified and publicized. Schrabisch (1930:18), for example, explored miles of the valleys of Chehocton (Shehawken) and Tock Pollock creeks (Buckingham Township, Wayne County, PA) without finding any type of sites.

D. Revisiting Select Variables, Environmental and Cultural - Recommendations

It is clear that the predictive value of the variable, distance to water, can change depending upon the specific geographic area or environmental zone involved. In order to capture the greatest percentage of sites, irrespective of area, a value of 300 meters should be employed. In cases where using this value will have a dramatic impact on the cost of a survey, values specific to the project area, and reflecting on the analyses presented in this report, should be employed.

In a study of a mountainous project area in Colorado vertical "distance" to a water source (difference in elevation from site area to water source) is the only surface water variable that is significantly different for site locations versus non-site locations (Kvamme 1985:220). Less than half of the reports reviewed by Harris (2013a) in the development of Pennsylvania's statewide predictive models considered the elevation of sites above surface water (see Table 3, this report). Vertical distance to surface water has only been considered as a potentially useful variable in relatively few projects in the Upper Delaware. This variable is included in the various analyses used by Harris and colleagues (2014c:Appendix C) to develop model sets that include the Pennsylvania portions of the Upper Delaware study area, but how it functioned as a stand-alone variable is not addressed. Vertical distances of 22 meters or less help to define high probability zones for sites in the Pocono Uplands (Perazio and Presler 2005:Table 2). However, associations with known site locations are not evaluated against the vertical distance of non-site locations to surface water. Given the terrain that characterizes large segments of the Upper Delaware the association of sites and vertical distances to water should be examined more closely in the future.

Modeling efforts are by default heavily reliant on environmental data reflecting historic/modern conditions and the biases that come with the use of such data. Examples of sources of more refined environmental data include:

-topographic maps of larger scale than USGS 7.5' quadrangles;

-wetland, natural area, and natural resources inventories by county and frequently township (e.g., Byram Township Environmental Commission 1994; Davis, Edinger, Anderson et al 1991; Davis, Edinger, Smith et al 1990, 1991; Pennsylvania Science Service and The Nature Conservancy 1995, 1999; Sussex County, New Jersey 2019);

-soil survey maps for the identification of springs, intermittent and first order streams not seen on USGS 7/5' quadrangles;

-data available from the USDA Natural Resources Conservation Service plant database;
-data available from the USDA Forest Service; and

-geologic mapping at the scale of 7.5' USGS quadrangles (e.g., Berg and Dodge 1981; Drake et al 1967, 1969).

Digital and GIS sources of data often exist at the state and county levels. Natural area and natural resources inventories can highlight sometimes unique settings and reflect micro-climate and edaphic factors that could be useful in refining predictive models and a better understanding of the environmental associations of known sites. These data will also improve ways of scoring or ranking the suitability of environmental zones or survey units (i.e., transects, grid units, hexagonal units) used to organize project areas for assessments of the potential for archaeological deposits. For example, Kudrle (2011) employed US Forest Service data in assessing site locations in the West Branch Valley of the Delaware River (Figure 13).

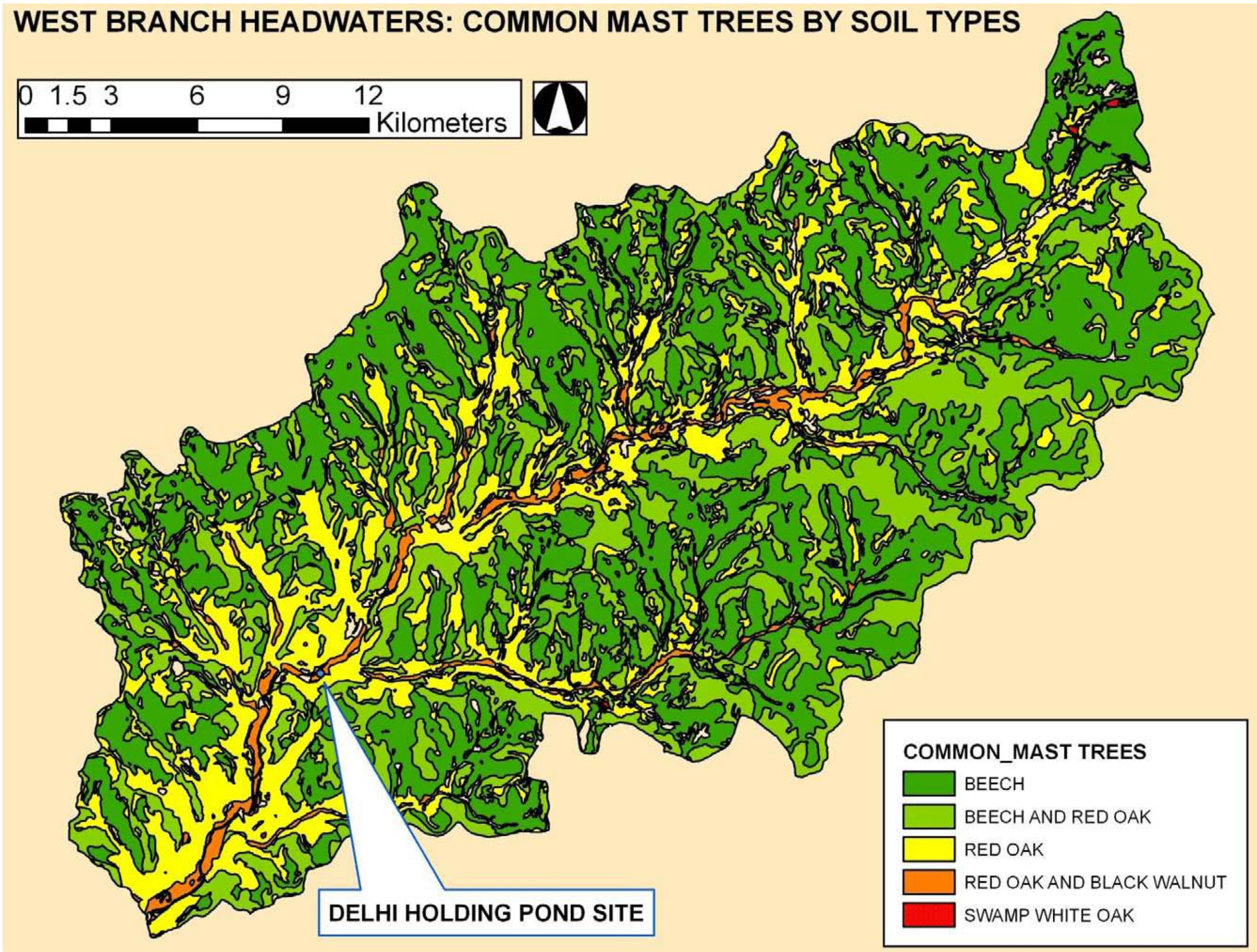

FIGURE 13. Modern mast trees per soil type, West Branch Basin of the Delaware River. Source: Kudrle 2011:Figure 25.

Evaluating environmental features associated with sites without reference to the type of occupation could potentially be confounding. For example, aspect might be a greater consideration on habitation sites than on overnight camps or forays. Some rockshelter data suggests that aspect is an important factor, while other studies have concluded that aspect for sites in general is not a significant variable.

The reliance on relatively modern forms of some types of environmental data remains a weakness in predictive modeling. Soils and edaphic factors have been used as proxies for speculating about the potential productivity of landscapes given their relative longevity on a landscape and potential to support different types of biotic communities. But soils develop in sedimentary deposits over varying lengths of time and are a function of a variety of other factors (i.e., climate, organisms, relief, parent material). They can reflect ancient conditions but one must not assume that their potential productivity remains stable throughout the period of their development. Ten thousand years ago the sediments of a floodplain may be rocky and sandy and supportive of a relatively narrow range of plant types and associated fauna. After years of alluvial deposition and the formation of one or more A horizons, their potential productivity has changed to the degree that more diverse biotic communities, and resources of potential interest to native peoples, might exist. Other soils may be excessively well drained early in their history but with the development of argillic B horizons and well defined structure, drainage can become less excessive to even poor on a seasonal basis.

At this point in time, however, it seems reasonable to use soils data for thinking about the productivity of environments in lieu of other sources of locally relevant information such as pollen/phytolith profiles, carbon isotope composition of soil organic matter, analysis of environmental charcoal, and the implications of botanical remains found on local archaeological sites. In general there is a need for more micro-regionally focused paleoenvironmental reconstructions (e.g., Dent 1979, 1985; Stinchcomb et al 2012, 2013, 2014). People adapt to the environmental conditions of the territories in which they live, and are impacted to varying degrees by the behaviors of neighbors living in adjacent, and perhaps differing environments.

Minimally we can identify times in the past during which cool-dry or warm-dry conditions may have adversely affected springs, intermittent and first order streams (Table 50). Reports should address how this may have impacted the results of a survey and the evaluation of the predictive model employed.

TABLE 50
Examples of Periods of Moisture Stress Potentially Impacting Paleoenvironments in the Region

Time Period Years BP	**Comments**	**References**
11,200-10,100	Younger Dryas, dry-cold	Vento et al in press; Yu 2000
8200	dry-cold	Roffet-Salque et al 2018:8705
6100	low soil moisture, low lake level	Li et al 2007
5300-3000	cool-dry, warm-dry	Stinchcomb et al 2012; Zhao et al 2010
4900-4600, 4800-2000	warm-dry, low lake levels	Shuman et al 2019; Yu et al 1997
4400	low soil moisture, low lake level	Li et al 2007
4200-3000, 4200-3900	Sub-Boreal, longer summers, low lake levels	Mayewski et al 2004; Shuman et al 2019
3000	low soil moisture, low lake level	Li et al 2007
2800-2100	low lake levels	Shuman et al 2019
1300, 1300-1200	low soil moisture, low lake levels	Li et al 2007; Shuman et al 2019
1100/1000-850/750	Medieval Warm Period	Cronin et al 2010; Vento et al in press

In general, there are a number of natural and cultural variables, used separately and in conjunction with others, that need additional attention in future modelling efforts, paralleling the complex associations investigated in the development of Pennsylvania's statewide predictive models for the region. Future analysis could benefit from considering:

- site function in relation to aspect/exposure;

- the relevance of a site's vertical distance to water;

- whether rock overhangs or potential shelters are more likely to be used if they occur within a foraging radius of a residential camp or base;

- the effectiveness of model variables within a foraging radius of a residential base or camp;

- the effectiveness of model variables within a foraging radius of a quarry or other significant material source;

- whether minor sources of toolstone and other materials are more likely to be used if they occur within a foraging radius of a residential camp or base;

- the effectiveness of model variables in areas in proximity to burial or mortuary loci, unique and potentially symbolic landscape features;

- the effectiveness of model variables for areas within natural travel corridors;

- the effectiveness of model variables for areas in proximity to historic trails; and

- the use of more detailed, and a wider range of data to characterize and rank the environmental potential or suitability of survey tracts in approaches that do so as a prelude to modeling more specific locations where sites might occur.

Based on a review of soil survey data and geomorphic settings, a sample of landscapes where sediments/soils of Pre-Clovis or Paleoindian age are likely to occur should be tested, regardless of how such landscapes conform to variables used to predict site locations.

E. Conclusion: Approaches in Modeling

James Ebert (e.g., 1988, 2000) is a long term critic of predictive modeling or more specifically the inductive approach to predictive modeling, i.e., developing models strictly on the basis of known site locations.

> The sort of predictive modeling advocated by and sold to government managers today proceeds from pattern recognition "upwards" to the projection of what archaeologists will discover in newly surveyed areas. It has nothing to do with explanation, a process that is far more detailed and which must go the other way (Ebert 1988:4).
>
> Site-centered, inductive predictive modeling ignores a vast body of anthropological and archaeological evidence and thought that emphasizes that people, the things they do, the places they do those things, and all other aspects of human behavior are a systemically organized whole. "Sites," in fact, are not independent entities at all, but components of systems – and their locations are dependent upon the locations of other components of that system, including other sites (Ebert 2000:131).

Sites occupy only a small percentage of the landscape so there are many more places were sites are not, then places where they are (Ebert 2000:131). As anyone who has done survey work in a

CRM context can attest, not all areas ranked as having a medium or high probability for site occurrence actually produce sites.

Even the simplest models are in reality a combination of inductive and deductive or explanatory approaches as should be obvious from the discussions throughout this report. Ecological approaches are typically the most readily operationalized given the types of data that are typically encountered and collected. And implicitly or otherwise, they assume that site settings are tied into adaptive or economic behaviors. I believe that most investigators would agree that there also are a variety of socio/cultural factors that are responsible for the patterns of environmental associations exhibited by sites. There are things, however, that could be incorporated into existing practices that would bring them more in line with ethnographically and archaeologically attested behaviors of hunter gatherers and ancient farmers. This report contains numerous suggestions about how that could be accomplished.

Simple models, those that employ a few variables, the primary one of which is distance to water, are capable of locating sites. But what is being missed? Are models that employ a few variables as effective as more complex ones? Previous discussions have shown how typical field strategies used during survey can under-represent small sites of varying function, regardless of the type of predictive model that in use. The lack of model evaluations at the conclusion of many CRM surveys makes addressing this issue a problem.

Even simple assessments of how many high probability settings were tested versus how many actually produced evidence of cultural activities would be useful in the ongoing improvement of modeling practices. Revisiting individual project reports and doing sufficient analysis to calculate the Kvamme Gain Statistic would be the most beneficial in this effort, as Harris and colleagues have done for a number of projects in Pennsylvania. It also is critical, regardless of an investigator's approach, that the degree to which non-site locations associated with the same variables a model uses to identify likely site settings be quantified for comparative purposes. Do environmental and site associations represent a real cultural pattern or do they simply reflect the nature of the background environment (Kvamme 1985:209)? Objective evidence must be provided to show "that the environmental phenomena examined are actually related to the presence or absence of sites" (Kvamme 1985:208).

The work of Harris and colleagues in Pennsylvania and portions of the Delaware Valley (e.g., Harris et al 2014c) has demonstrated that the answer is "no" to the question of whether simple models are as effective in locating sites as complex models. The variables that must be considered in assessing the location of known archaeological sites and predicting others are numerous and integrated in a systemic fashion. The importance of any specific variable in the system can vary by environmental zone or the scale of the geographic area in which analyses of site settings takes place. The evaluations of both simple and complex models presented in this report emphasize that predictive models should be generated for specific physiographic regions or environmental zones, and not extrapolated across divergent settings.

Yet even these complex models retain the weakness of being based on the analysis of the settings of known sites, and all of the biases that are inherent to such databases. Recent survey efforts by local archaeologist, Del Beck, in conjunction with myself and archaeologists from the

State Museum of Pennsylvania, have located 23 upland sites on portions of the Broad Mountain in the Lehigh River Gorge of the Delaware River basin. The sites represent the Middle Archaic through Late Woodland periods based on the range of diagnostic artifacts observed. Assemblages vary from small lithic scatters to those representing the diverse activities associated with camps, including caches. These same areas are ranked in the Pennsylvania Statewide model for this area has having a low probability for the occurrence of archaeological sites.

It was anticipated that updating the Pennsylvania statewide models will be necessary as more systematic coverage of environmental settings under-represented in the existing database takes place. Standardized evaluations and reporting standards regarding the use and effectiveness of predictive models have been instituted (PA SHPO 2017:23-24; see Table 15 and associated narrative, this report). This practice should be emulated in New Jersey.

A separate but equally important question is whether simple predictive models allow a CRM archaeologist to effectively demonstrate to an agency that an undertaking has made a reasonable and good faith effort to identify historic properties. As noted, inappropriate field methods, regardless of the type of model employed, can fail to discover small sites whose lack of significance should not be a foregone conclusion. Suggestions for revising field methods in order to increase the likelihood of finding small sites have been provided above. At a minimum, it should be required that all shovel test pit transects be unaligned in order to decrease the size of areas not tested. In the end, however, it matters how investigators and agency personnel perceive the mandate to make a reasonable effort to identify historic properties, or respond to the funding, scheduling, or political constraints associated with individual projects.

We acknowledge that the environment has changed over the course of pre-contact times yet rely on some types of environmental data that reflect historic/modern conditions. There is no clear solution to this problem other than to task investigators to address in project reports how environmental change may have affected their models and survey results. Examples of issues to address include: changes in the drainage characteristics of certain landforms; distance to surface water given the meandering of streams and the areal extent of alluvial soils; and the viability of springs, intermittent and first order streams. Obviously these factors also will have an impact on the nature of plant and animal communities associated with different landscapes.

Considering the variety of models that have been reviewed, I recommend the development of an approach to modeling that is hierarchical in formulation, combining aspects of inductive and deductive models. The process would begin with the scoring and ranking of the environmental productivity or suitability of spatial units used to subdivide the quadrangle(s) or drainage basin(s) within which a survey project is located. This initial step would mimic and modify procedures previously employed by Beckerman (1978), Custer et al 1986), Dekin et al (1983), Eveleigh et al (1983), Eveleigh (1984a, b), Hasenstab (1983, 1984), Hay and Hatch (1980), Kuznar (1984a, b), Marcopul (2007), Mikolic and Albright (2012), and Wells (1981). A wide range of data would be used to characterize a unit's resource potential following suggestions made in previous report sections. The cultural factors included in the scoring would include:

- existence of a known residential site(s) within a unit;

- inclusion of all or part of a foraging radius in a unit related to a known residential site;

- existence of a known quarry or material source within a unit;

- inclusion of all or part of a foraging radius in a unit related to a known quarry or material source;

- existence of known burial or mortuary loci within a unit;

- inclusion of all or part of a foraging radius in a unit related to a known burial or mortuary loci;

- existence of unique and potentially symbolic landscape features within a unit;

- inclusion of all or part of a foraging radius in a unit related to unique and potentially symbolic landscape features

- existence of part of a natural travel route within a unit; and

- existence of part of a historic trail or path within a unit.

The use of these features in unit scoring and eventual ranking would benefit from first evaluating their potential relationship with sites following suggestions outlined in the previous report section. Following the rationale of Dekin et al (1983) I recommend the use of hexagonal units measuring 1 kilometer per side to subdivide quadrangles or drainage basins in the Upper Delaware. Modification of the size of hexagonal units would depend on the heterogeneity or homogeneity of area environments.

Following the ranking (high, medium, low) of scored spatial units, suites of variables typically used to identify potential site locations would be applied to each unit. Ideally, regression analysis of environmental variables associated with a large sample of known sites from the area or similar environmental zone would be used to make intra-unit predictions. Predicting potential site locations *following* the identification of the most physically and culturally attractive areas within a geographic area attempts to get around the problem that there are more possible site locations than actual sites. It is difficult to assess the benefit of this recommended approach with the demonstrated effectiveness of Pennsylvania's statewide models developed by Harris and colleagues. In fact, the complex series of variables, variable combinations, and analyses they employ may achieve the end via a different process..

Operationalizing the recommended approach in the context of small CRM projects or those with linear right-of-ways will be time consuming, and therefore more expensive to enact. This has become a moot point for Pennsylvania portions of the Upper Delaware where the use of the relevant statewide model is proscribed. This is not the case in New Jersey or New York where investigators dealing with small projects are more likely to borrow or elaborate upon models previously employed in adjacent or similar environmental zones. A state-based project(s) that adapts best, or potentially useful practices to the environmental diversity found within their boundaries should be pursued. Lacking this, standardized evaluations and reporting of model effectiveness must be required.

There is a large and diverse body of work that any investigator must digest in contemplating the use of predictive models in an archaeological survey. As a background reference to this body of work, this report hopefully will facilitate such efforts, providing food for thought in developing future practices. Beyond the practical concern of predicting site locations for survey and management purposes, working with models will eventually help us to recognize the cultural rules that ancient peoples used to situate themselves on the landscape.

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