SECTION 10.0 FEATURE FORMATION: BASINS

INTRODUCTION

One of the most ubiquitous feature types at Hickory Bluff were basin features of varying sizes and shapes. While culturally constructed basin features may sometimes be differentiated from natural features based on their observed morphology and content, postdepositional processes operate to modify and mimic cultural features, causing problems in determining specific formation of the entity. Moreover, since cultural and natural agents often overlap and interact in the context of basin formation and use, it is worthwhile to consider these archaeological manifestations as the result of complex processes.

The formation of basin features is of particular relevance to archaeological investigations in Delaware. Extensive archaeological work in the state has resulted in the identification of thousands of basin features, the exact nature of which remain undetermined. During the past decade, there has been an on-going debate among archaeologists working in the state concerning the interpretation of these subsurface soil anomalies. Many hundreds of these anomalies have been excavated on sites in Delaware; over two hundred large pits were reported from the Leipsic site (Custer et al. 1994), with hundreds more reported from both Carey Farm and Island Farm (Custer et al. 1995b). These anomalies have been identified as the signature remains of semi-subterranean dwellings, or “pit houses” (Custer et al. 1994:36-38; Custer and Silber 1995; Custer et al. 1995b). Others have suggested that they are the remnants of naturally occurring tree throws (e.g., Mueller and Cavallo 1995).

The formation of basin features was examined using a variety of research avenues. Ethnohistorical and experimental sources were reviewed and three-dimensional computer maps of basins and tree anomalies were created to examine the range of variation found within feature types. The information gathered from these sources was synthesized and used to model the various processes that may have operated to form basin features.

Prior to addressing possible basin formation, a brief review of the archaeological evidence for semi-subterranean dwellings, or pit houses in Delaware is reviewed. This is followed by a synopsis of the tree throw alternative for the formation of large basin features. In that context, existing scientific documentation of tree throw morphology is presented in detail. Archaeological documentation of extant tree disturbances on Hickory Bluff is then presented. The purpose of this study was to assess the actual below ground configurations of local tree species in order to gain insights into the precise nature of their archaeological traces. The morphology of modern tree throws on Hickory Bluff and other nearby sites is also documented. The next component in the investigation of potential basin formation details the results of the experimental undertakings. This study provides insights in to the progressive morphological changes that occur to, and within, replicated basin feature excavations over time. Information provided by this study proved valuable in assessing what changes occur to excavations and how a known basin morphology may differ from its original form when encountered in archaeological contexts. The range of morphology and variation within both basin features and the documented tree disturbances are presented and illustrated with the aid of computer generated three-dimensional contour maps. These maps helped to visualize the differences within and between feature types and more accurately depict the encountered archaeological residues.

SEMI-SUBTERRANEAN STRUCTURES IN DELAWARE

Archaeological remains of semi-subterranean shelters were first reported at the Poplar Thicket (7S-G-22) and Island Field (7K-F-17) sites (Griffith and Artusy 1975). At Poplar Thicket, a large, shallow rectilinear pit feature was excavated. This pit, which measured 3.0 by 3.8 Meters (m), showed very regular, steeply sloping sides and a flat bottom. Internal features, including a central hearth and numerous post molds, were also recorded (Griffith and Artusy 1975:5). The Island Field example was similar in dimension, though it was oval in plan. An internal hearth and post molds were present (Griffith and Artusy 1975:6). Both these features contained Townsend series ceramics, dating them to the Late Woodland period.

Very large ovoid to rectangular flat-bottom pits were also reported from the Mispillion site (7S-A-1) and the Warrinton site (7S-G-14) (Griffith and Artusy 1975). Illustrated examples from the respective sites had maximum lengths of 3.6 m and 3.2 m (Griffith and Artusy 1975:2-3). Though lacking obvious internal features, these large pits were also interpreted as the remains of semi-subterranean shelters. At least one example from each site contained Townsend Series ceramics and triangular projectile points (Griffith and Artusy 1975:1-2).

Investigations at the Delaware Park site in New Castle County identified nearly 200 subsurface pit features of various sizes (Thomas 1981). Four of these features were interpreted as possibly representing "domiciles" or "shelters for some other human activity" (Thomas 1981:V-17). These features, categorized as Type B, were very large shallow basins with both sloping and flat bottoms. Feature 94, illustrated and described in detail in the report, contained a small pit interpreted as an internal hearth. Also noted during excavation were possible interior and exterior post molds and a degree of compaction of the pit floor (Thomas 1981:V-17). A radiocarbon date of 1850 B.C. was obtained from Feature 94, while a second Type B feature yielded a date of 790 B.C. (Thomas 1981:IV-44).

A possible pithouse finding was also documented at the Clyde Farm Site (7NC-E-6A) (Custer 1989). On Clyde Farm "in an area of approximately thirty-five square meters, a number of features were discovered including a platform hearth, possible storage pits, and a pit house" (Custer 1989:197). A single radiocarbon date of 1005 B.C. was obtained from the platform hearth. Based on their horizontal spatial association, these features were collectively interpreted as a household cluster (Custer 1989:198). In that regard, the large pit (house) feature, the platform hearth and a storage pit, together with a conjectural area of tool production, were illustrated as an idealized "Feature Plot" (Custer 1989:187). The concept of household clusters was used to interpret the numerous subsurface anomalies found on Snapp, Carey Farm, Leipsic and other site locations where anomalies were seen as the signature remains of plow truncated semi-subterranean dwellings (Custer 1994:50-66).

The conceptual template for large basins representing pit houses was based on a single finding made on the Snapp site (7NC-G-101) where a complex of features was encountered at the foot of a minor slope. The addition of colluvial soil had protected this area from the extensive plow truncation evident across the rest of the site. Designated Feature 153, the complex consisted of a large D-shaped basin set in one end of a much larger, shallow feature. A third pit was defined in the approximate center of the larger feature. The cluster of pits was roughly enclosed by a pattern of nine, irregularly spaced post molds. The Feature 153 complex was interpreted as a dwelling composed of a shallow "basement", or living area, with a "sub-basement" storage facility located at one end. The central pit was interpreted as a hearth, with the post mold pattern representing a superstructure constructed over the below-grade house floor (Custer and Silber 1995:43-52).

The interpretation of a remnant “sub-basement” within a semi-subterranean structure was applied to a large number of the Snapp anomalies (Custer and Silber 1995) and extended to other sites on which similar anomalies were present (Figure 10.1). According to this model, virtually all of the hundreds of large anomalies identified on these sites represent house locations (Custer et al. 1994; Custer and Silber 1995; Custer et al. 1995b). On the Leipsic site alone, a total of 197 individual anomalies were interpreted as sub-basement storage facilities located within dwellings, all other traces of which have been lost to extensive plowing and soil deflation (Custer et al. 1994:36-38). Further, the “household cluster” definition is applied to many of the anomaly locations. The incidence and frequency of these “household clusters” was then used to make broad inferences on site function, occupation seasonality and regional settlement patterns (Custer et al. 1994; Custer and Silber 1995; Custer et al. 1995b).

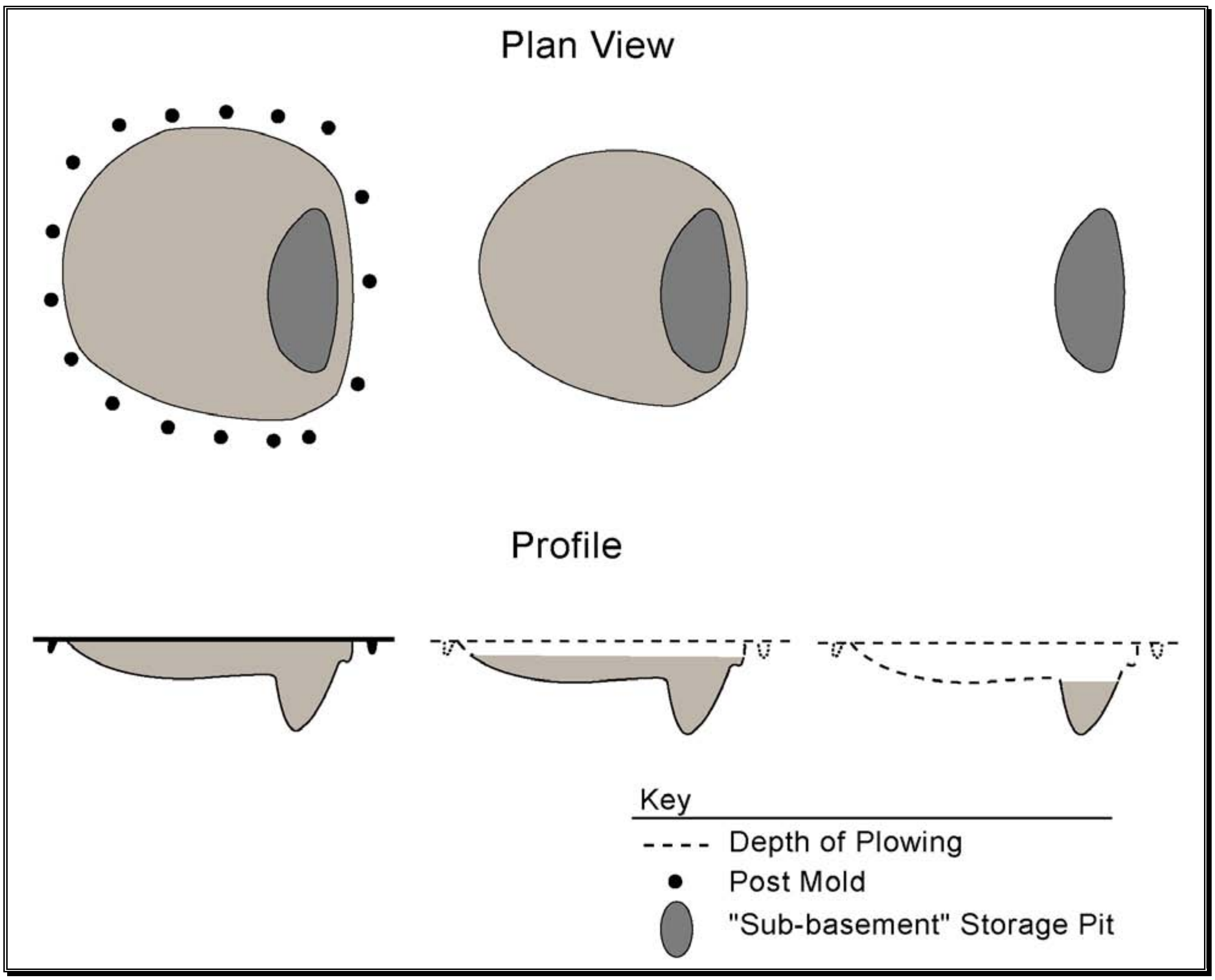

Figure 10.1 Proposed Taphonomy of Delmarva Pithouse Features (Custer 1994: Figure 30**)**

THE ROLE OF TREES

The Tree Throw Alternative

The tree throw hypothesis for similar archaeological feature phenomena was indicated at the Hollingsworth Farm site along Elk Creek in Elkton, Maryland (Thomas and Payne 1981). Thirty-seven of the large features investigated during excavations were interpreted as tree throws. These pit features were typically circular to ovoid in shape with rounded or irregularly shaped bottoms and were characterized by inclusion of dark, organic-laden soils and concentrations of Native American artifacts mixed with occasional historical artifacts (Thomas and Payne 1981). During subsequent excavations conducted at the Charles Robinson Plantation in New Castle County (Thomas 1982), thirty D- or kidney-shaped subsurface anomalies were identified, all of which had been truncated by plowing. Thomas suggested that tree throws might be the causal factor in the creation of these and other similar features commonly encountered elsewhere within the state of Delaware.

More recently, Mueller and Cavallo have explored the alternative tree throw hypothesis as a result of excavations conducted by Rutgers University at the Gabor site in northern Delaware (Cavallo n.d.). Several D-shaped proposed "pit house" features were interpreted as naturally occurring tree throws due to lack of organic staining, internal stratigraphy, associated post molds, and paucity of artifacts (Mueller and Cavallo 1995). A review of publications, related to natural tree throws and archaeological investigations of unequivocal semi-subterranean pit houses and other D-shaped features, was conducted. These investigators concluded that, based on all available evidence, the most reasonable interpretation of the D-shaped pits was that they were a result of naturally occurring tree throws and not cultural activity. These findings were presented in papers at the 1995 meetings of the Archaeological Society of New Jersey (Cavallo 1995) and the Eastern States Archaeological Federation (Mueller and Cavallo 1995).

Subsurface Tree Physiology and Morphology

A tree's roots comprise an elaborate and sophisticated system that performs three basic functions: to absorb moisture and soil nutrients, to transport these materials, and to provide anchorage and support. While the above ground portion of a typical mature tree is easily observed, a vast root system lies hidden below ground. For example, a single rye plant has been shown to possess 14 million individual roots collectively totaling over 375 miles in length (Farb 1961:95). By comparison, the total extent of a mature hardwood tree's root system is so vast that it would be a near impossible task to measure it. Deciduous tree species such as oaks, hickories, and walnuts have systems that could be thought of as foreshortened mirror image of the tree's crown. Roots continually branch in all directions, with each branch carrying its own growing tip (Farb 1961:95). These growing tips, which can number in the millions, essentially possess a sensory function. They act like a probing finger, actively avoiding hard objects and seeking out soft earth which they penetrate with a corkscrew motion (Farb 1961:94).

The absorption function of the root system is carried out by thousand of tiny root hairs that extend out perpendicularly from a short stretch of new root just behind the growing tip. This area just behind the growing tip is the only portion of the root that actively grows in length (Farb 1961:94). These new roots, which have a diameter of no more than a piece of string, function in an absorbing capacity for only a short time. After a few weeks, the root hairs die and the root ceases to absorb. From then on, the root grows in diameter only and its role remains to provide transport and anchorage (Farb 1961:94). In this manner, a tree must continually branch out new small thin new roots that seek out water and essential nutrients. Over time, these new roots grow to form a vast web that essentially develops in situ.

The anchoring ability of a tree root system is particularly remarkable when one considers that a mature trunk can reach upwards of a hundred or more feet, after which it branches out into a wide crown. Not only does this represent a huge mass, but the crown acts like a sail under windy or stormy condition. Further yet, this force is applied to the base of the trunk where the ground can act as a fulcrum point. Much of the stability exhibited by large trees comes from the mature roots that radiate out in all directions just below the surface, acting as guy wires, while additional anchorage is provided by tap roots than can plumb considerable depths (Farb 1961:95). While the major root elements can extend outwards as far as the edge of the crown, and can also penetrate to considerable depths, the actual immobilizing strength of the root system comes from the vast web of tiny root that spread out from the larger, main root members. The tip areas of these smallest roots contain untold numbers of root hairs that grip the soil so tenaciously that they cannot be removed without being broken (Farb 1964:94).

The Morphology of Tree Throws

The large majority of tree throw studies have been conducted within the fields of forestry and ecology, undertaken to determine the impact of tree throws on the forest environment and subsequent pedogenic processes. A review of this literature revealed a wide variety of surface and subsurface morphologies resulting from tree throws, dependent on many climactic and pedological conditions.

Four primary factors have been identified as creating tree throws: wind, weight of ice or snow, the fall of an adjacent tree, and people (Langohr 1993). Wind-related tree throws may result in the breaking of the tree trunk or the uprooting of the entire tree (Langohr 1993). Environmental variables associated with wind-related tree throws include seasonal wind intensity, storm events (i.e., hurricanes and tornadoes), precipitation (affecting soil saturation and stability), landform, and depth to bedrock. The last two variables also contribute to the variation in tree root systems.

Typically, a tree throw forms a paired pit and mound, or cradle and knoll topography. The pit, or cradle, is formed as tree roots are ripped from the soil, carrying with them surrounding sediments that cling to the root mass. As the displaced root plate decays, soil slumps back into the pit and onto the undisturbed adjacent ground surface forming a mound, or knoll, that marks the resting place of the fallen tree (e.g., Lutz 1960; Schaetzl et al. 1990; Wood and Johnson 1978). Tree throws are commonly identified by the presence of these pit/mound pairs and are widespread throughout forested regions (Beke and McKeague 1984; Cremeans and Kalisz 1988; Stephens 1956). Eight variations of tree throws and their associated soil stratigraphies have been identified (Langhor 1993) (Figure 10.2).

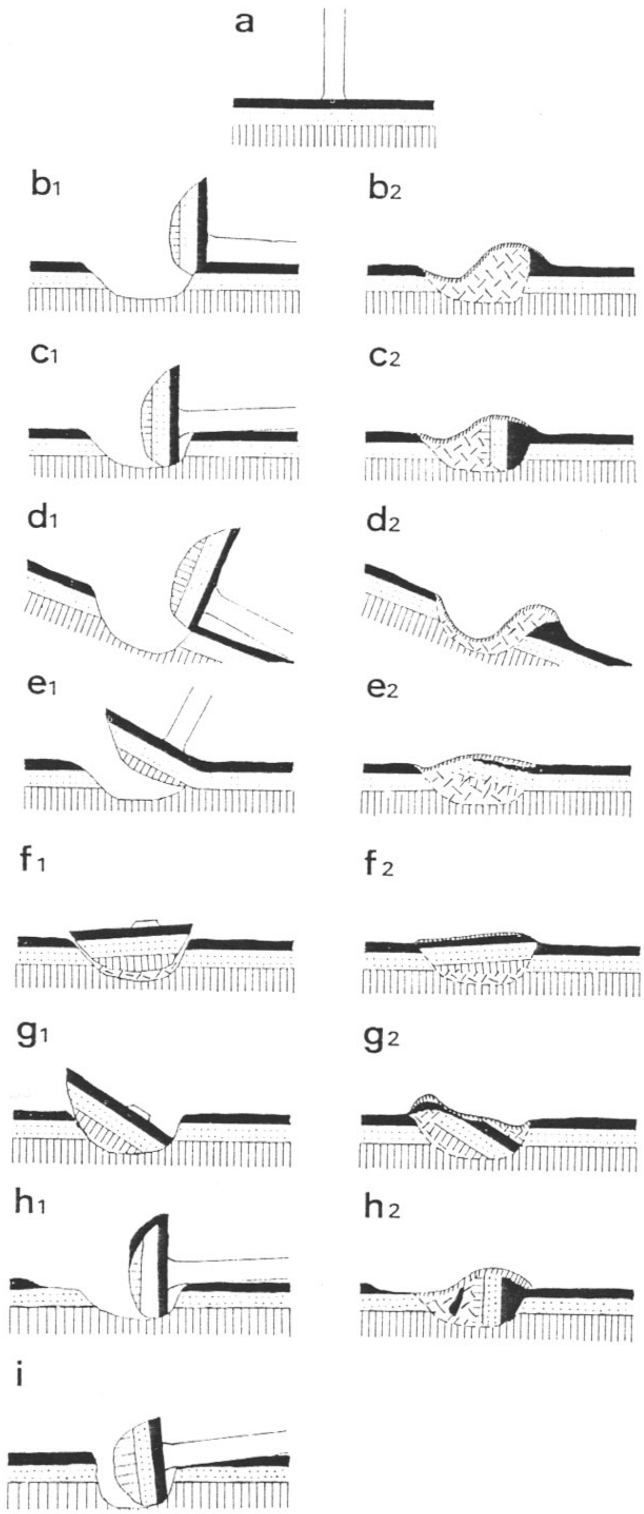

Figure 10.2 Eight Variations of Tree Throws and Associated Stratigraphies
(Langhor 1993: Figure 1**)**

Studies of the size and depth of tree throw pits have shown that initial dimensions depend largely upon the size of the tree and its root structure. Conversely, the quantity of sediment that returns to the pit through slump and wash processes will determine its later dimensions (Beatty and Stone 1986; Putz 1983). Many varied factors affecting the slump and wash process must be taken into account in any tree throw study. These factors include soil characteristics such as texture, structure, and gravel content; regional climate (e.g., precipitation rates and freeze-thaw activity; decay rate of the root mass); and faunalturbation both within the pit and adjacent mound (Lyford and MacLean 1966; Putz 1983). Ground slope is yet another variable that determines the rate and amount of pit infilling. On gentle slopes, pits are often partially or completely refilled by uplifted soils (Denny and Goodlett 1956; Schaetzl and Follmer 1990), whereas trees that fall on steep slopes generally fall downslope and are infilled by slopewash and gravity-transported sediments (Cremeans and Kalisz 1988).

Tree throws may also be classified according to the shape and placement of the resulting pits. Simple tree throw pits appear ovoid to D-shaped in plan-view, but are almost never circular (Langhor 1993) (Figure 10.3). Crescentic pits may be caused by slight backward displacement during treefall (Beatty and Stone 1986), though this may simply be a result of incomplete data recovery (Langhor 1993). Partial, but incomplete backward displacement of the root mass may cause the formation of two smaller pits on either side of a mound (Nielson 1963). Complete backward displacement may form a pit on the lee side of the mound, thus complicating future determination of the direction of the tree throw (Schaetzl et al. 1989). Nielson (1963) has also suggested that the latter pit-mound arrangement is caused by trees falling against other nearby trees, by trees falling upslope, or by large boulders present near the base of the tree that act as pivot points during the treefall process. Tree throw cradle profiles exhibit a characteristic morphology: one edge is steep-sided and the other is gently sloping. The steep-sided deepest portion indicates the leeside of the tree throw whereas the gentle sloping shallow side represents the windward side (Crombe' 1993).

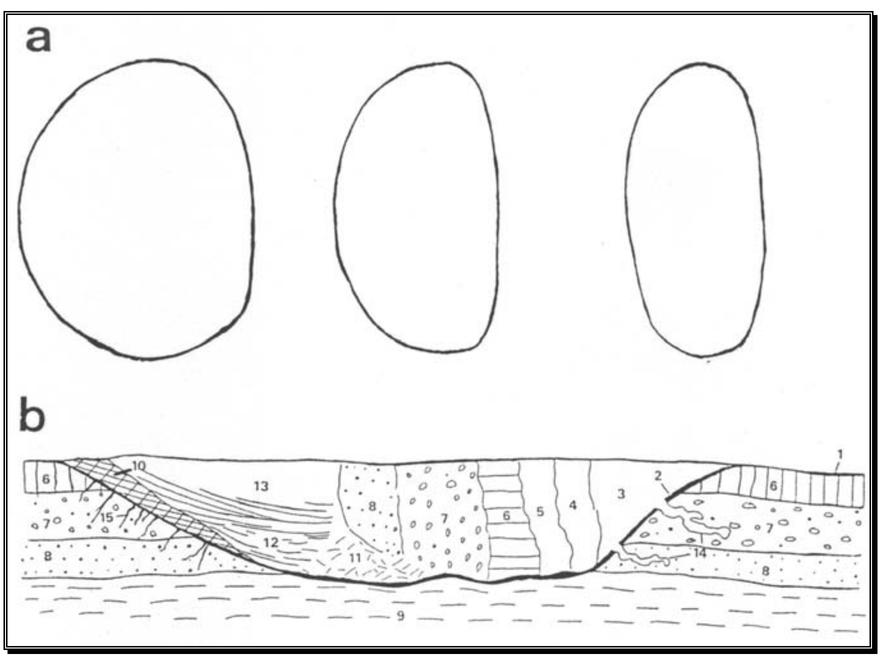

Figure 10.3 Typical Planview and Profile of Three Throws (Langhor 1993: Figure 2**)**

Tree throw mounds are characterized by the slope of their sides or the relief from the mound crest to the pit bottom. Due to erosion and other infilling processes, mound distinctiveness decreases significantly over time (Denny and Goodlett 1956). Sediment characteristics aid in determinations of both mound longevity and slope deterioration. In a comparative study, Nielson found that mounds formed in silty sediments had a steeper average slope (14°) than did those that occur in sandier soils (10°). Stone (1975) observed slopes of 13.30° on mounds formed in gravel-free soils that were estimated to be over 250 years old (cited in Schaetzl et al. 1990). The horizontal relationship between mound crest and pit bottom also changes over time, as sediments from the mound fall into the nearest part of the pit, progressively shifting the deepest point away from the crest of the mound (Schaetzl et al. 1990).

As previously noted, the amount of soil disturbed is largely dependent on the size of the tree uprooted and the structure of its root system. The uprooting of large trees will result in the disturbance of a greater surface area than small ones, though they will not necessarily cause disturbance of a greater depth (Hall 1988). The extent of the disturbance also depends on the health of a tree when it falls. Dead or dying trees will cause less significant disturbance than healthy trees, as root breakage during uprooting will be greater when the root system has already begun to decay (Swanson et al. 1982). Several studies have been conducted correlating trunk diameter at breast height (DBH) to area of soil disturbed by uprooting. Cremeans and Kalisz (1988) found a positive correlation between DBH and the area of disturbance, calculating separate regressions for both healthy and dead trees. Burns (1981) also examined patterns of size vs. disturbance and found that the area disturbed increases up to approximately 40 centimeters (cm) DBH, but that root systems of larger trees did not typically affect a larger subsurface area.

Primary pedoturbation results from the slump and erosion of sediments clinging to the root plate. Uplifted soil horizons may appear discontinuous and irregular within areas of redeposition (Johnson et al. 1987) (Figure 10.4), or may appear as an interfingering of disturbed soil horizons (Hall 1988; Lutz and Griswold 1939). The appearance of redeposited soils largely depends upon the rate of decay of the root plate itself. Under circumstances of prolonged decay, soil horizons become homogenous due to slowed slump and wash processes, resulting in total loss of the distinctiveness of original horizons (Schaetzl et al. 1990). In contrast, rapid decay of the root mass, as is common in hardwoods (Beatty and Stone 1986), produces a more heterogeneous pattern of redeposition. Soil falls from the root mass in clumps too quickly for surface pedoturbation processes to cause significant mixing of disturbed horizons (Hall 1988; Troedsson and Lyford 1973). Soil horizons may appear folded over one another (Beatty and Stone 1986; Lutz and Griswold 1939; Veneman et al. 1984). Complete inversion of original soil profiles may occur on steep slopes where uprooted trees fall downhill (Figure 10.2), particularly in cases where fires subsequently occur (Figure 10.5). As the trunk decays or is burned, the root plate falls upside-down, resulting in inverted stratigraphy (Schaetzl 1986).

Gravels, rocks, and large soil clasts, where present, are also brought to the surface along with uprooted sediments (Lutz 1960). These inclusions are subsequently reburied within redeposited soils by slope and wash processes. Archaeological artifacts found within disturbed horizons are also mixed and reburied by the same processes of pedoturbation (Wood and Johnson 1978). Frequently, patterns of redeposition of soil inclusions can indicate the presence of tree throws long after all resulting surface topography has been obliterated (Beatty and Stone 1986). As sediments wash from the root plate, gravels and other inclusions may be concentrated as an armor or lag (Denny and Goodlett 1956; Johnson 1990) (Figure 10.6). Uprooting may also form mounds of surface stone pavements surrounded by fine sediments and vice versa (Denny and Goodlett 1956).

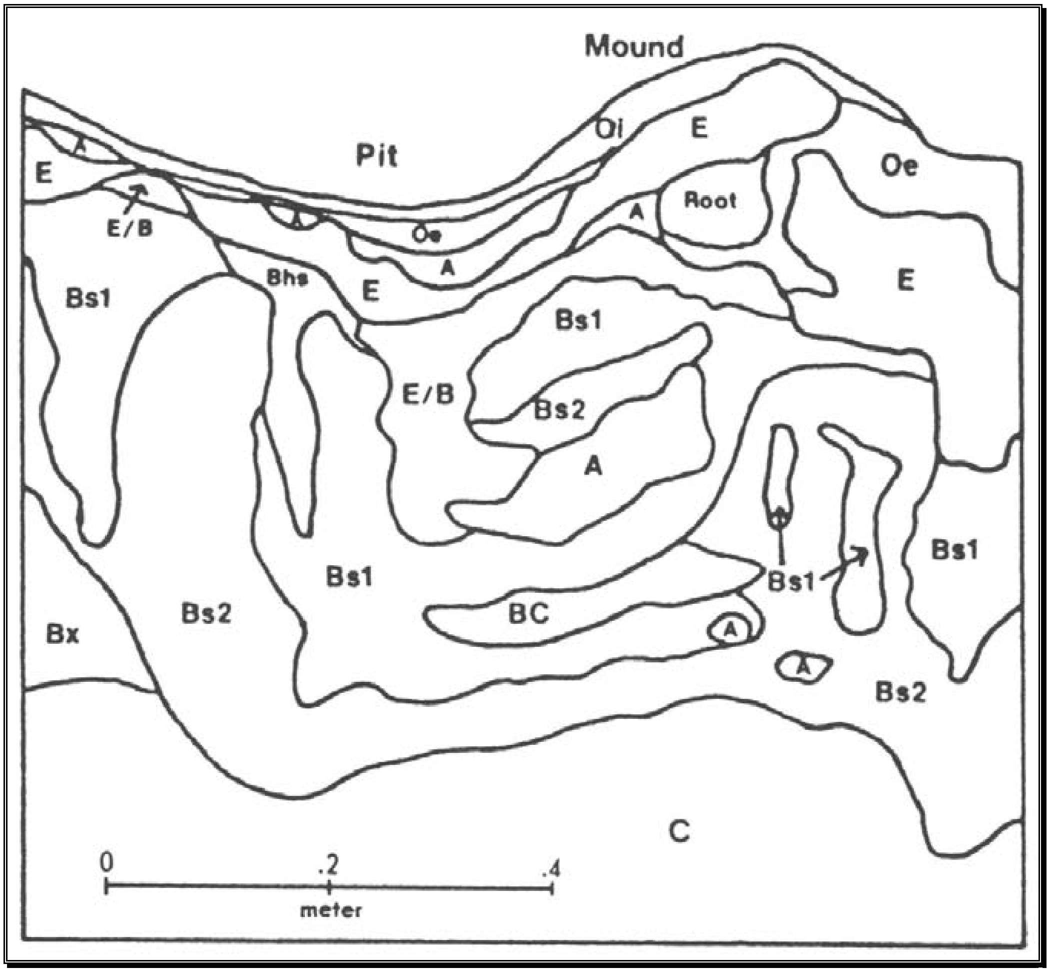

Figure 10.4 Pit/Mound Tree Fall Profile (Schaetzl 1986: Figure 3**)**

Bisection profiles of tree throw depressions and mounds have clearly demonstrated their internal stratigraphic complexity (Armson and Fessenden 1973; Denny and Goodlett 1956; Hall 1988; Johnson et al. 1987; Schaetzl 1986). Where disturbance extends into the B-horizon, mounds frequently consist of a core of B-horizon sediments with interspersed smaller clasts of A- and E-horizons, presumably due to the comparative thinness of the latter horizons (Lyford 1973; Lyford and MacLean 1966; Schaetzl 1986) (Figure 10.7). Karparchevskiy et al. (1968) found that in wet, organically rich soils, uprooting of shallowly rooted trees may lead to mounds composed exclusively of A- and O-horizon sediments. They also noted that E-horizons are most frequently discontinuous across pit-mound pairs, unless their formation post-dates the uprooting event (Karparchevskiy et al. 1968 in Schaetzl et al. 1990). E-horizon sediments often terminate at the edge of the pit (Lutz and Griswold 1939), but may continue beneath the adjacent mound (Schaetzl 1986). Mound sediments are often horizontally stratified, with lower B-horizon soils located proximal to the pit and upper horizon materials positioned on the distal side of the mound (Denny and Goodlett 1956).

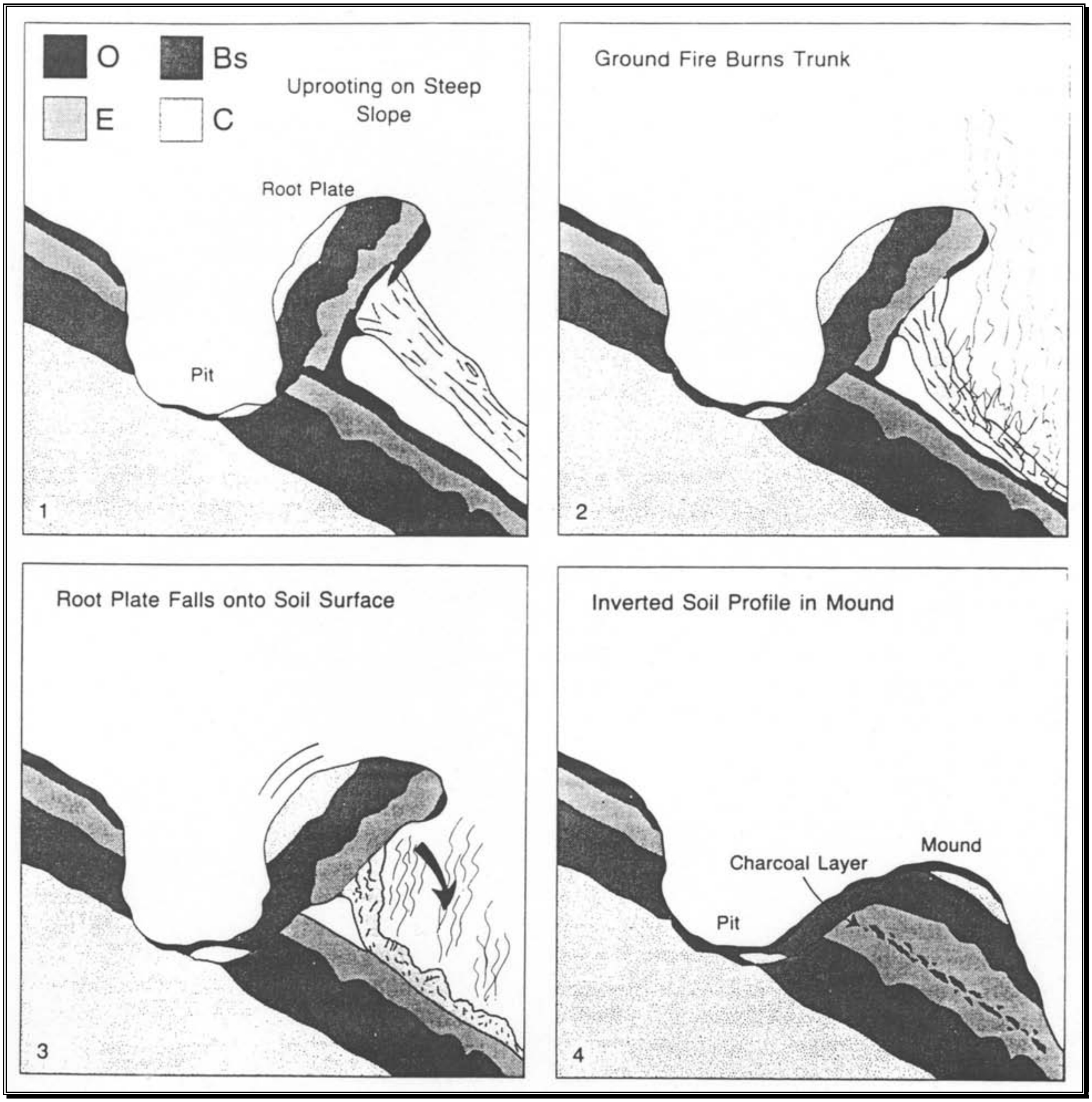

Figure 10.5 Complete Inversion Tree Fall Profile (Schaetzl and Follmer 1990: Figure 4**)**

Tree throw profiles are typically characterized by unusually thickened O-horizons due to litter accumulation within the pit (Armson and Fessenden 1973; Hall 1988). Studies of litter accumulation have found a mean litter thickness of 12 cm in pits, in contrast to a mean of 4.4 cm on mounds (Lyford and MacLean 1966). Infilling of pits by sediments from the root plate and mound may also cause thickened A-horizons within the pits, or buried organic horizons (Lutz 1940; Troedsson and Lyford 1973). Beatty and Stone (1986) found that soil moisture content and thickness of O-, A-, and E-horizons are typically greatest in pits and least within mounds, in contrast to undisturbed surrounding areas, which are intermediate in these characteristics.

Figure 10.6 "Armor/Lag" Deposit Tree Fall (Schaetzel et al. 1990: Figure 1**)**

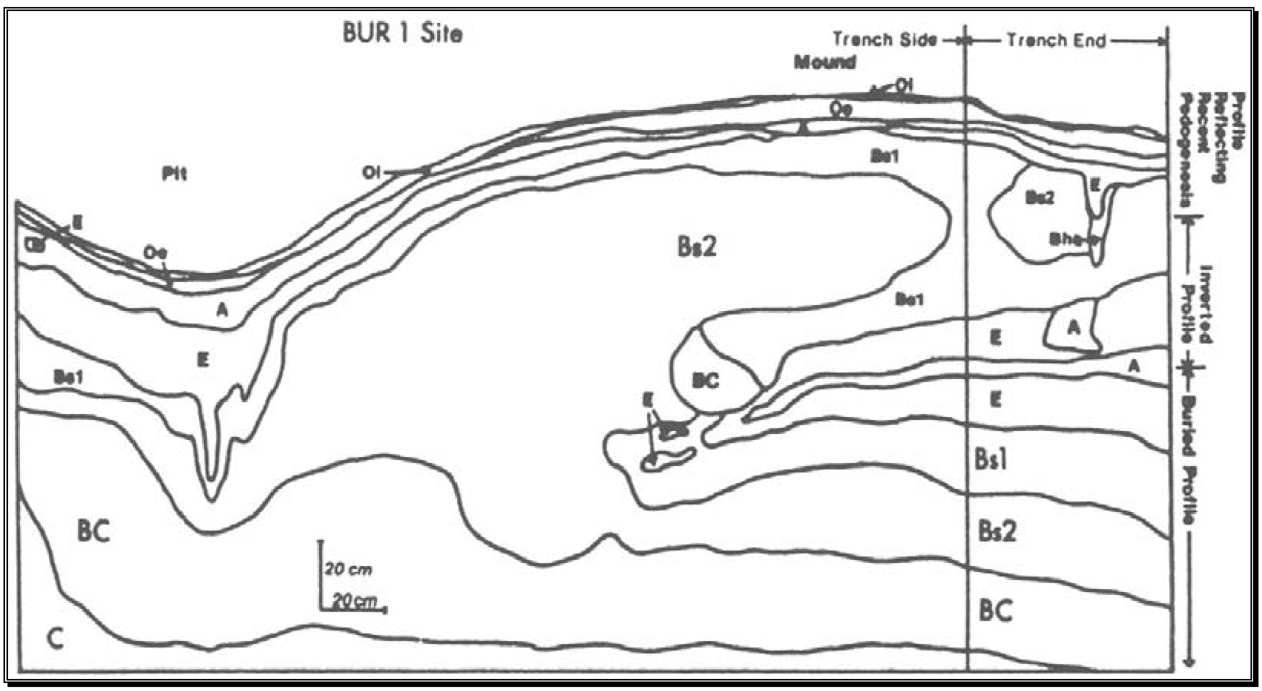

Figure 10.7 Tree Fall Mound Showing B-Horizon Core Sediments (Schaetzl 1986: Figure 2**)**

The primary influence of tree throws on pedogenesis occurs through the spatial redistribution of litter and soil moisture content, resulting in accelerated soil development beneath pits (Schaetzl et al. 1990). Frequently, in pits lying beneath trees that produce acidic litter, strongly developed podozolic soils with thickened E-horizons are found, suggesting concentrated leaching in these areas (Burns et al. 1984; Lutz 1940). In a study of Pennsylvania tree throws, Denny and Goodlett (1956) observed pit soils with thin, Podozol-like profiles, in contrast to a lack of recognizable stratigraphy within adjacent mounds. Upon finding well-developed Spodozols in pits and Inceptisols in mounds, Veneman et al. (1984) concluded that precipitation flowing laterally through the O-horizon into the pits concentrated both water and organic acids within them. Description of tree throw pits over 500 years old, also containing well-developed Spodozol profiles with minimal soil development in adjacent mounds, suggest that rates of post-uprooting pedogenesis are least in mounds and greatest within pits (Schaetzl et al. 1990).

Soil characteristics, and thus classification, may also change as a result of past pedoturbation (e.g., the interrupted and cyclic horizon character of many Spodozols) (McKeague et al. 1969). Lutz and Griswold (1939) have suggested that interfingering of E- into B-horizons may result from the infilling of decaying root channels (Figure 10.8). E/B- and B/E-horizons, common to many forest soils, may therefore be the result of tree throws (Schaetzl et al. 1990). However, Veneman et al. (1984) concluded that, despite the fact that 25 percent of the surface in their study area in Massachusetts was characterized by pit-mound topography, only 6 percent of those soils had been changed taxonomically by uprooting events.

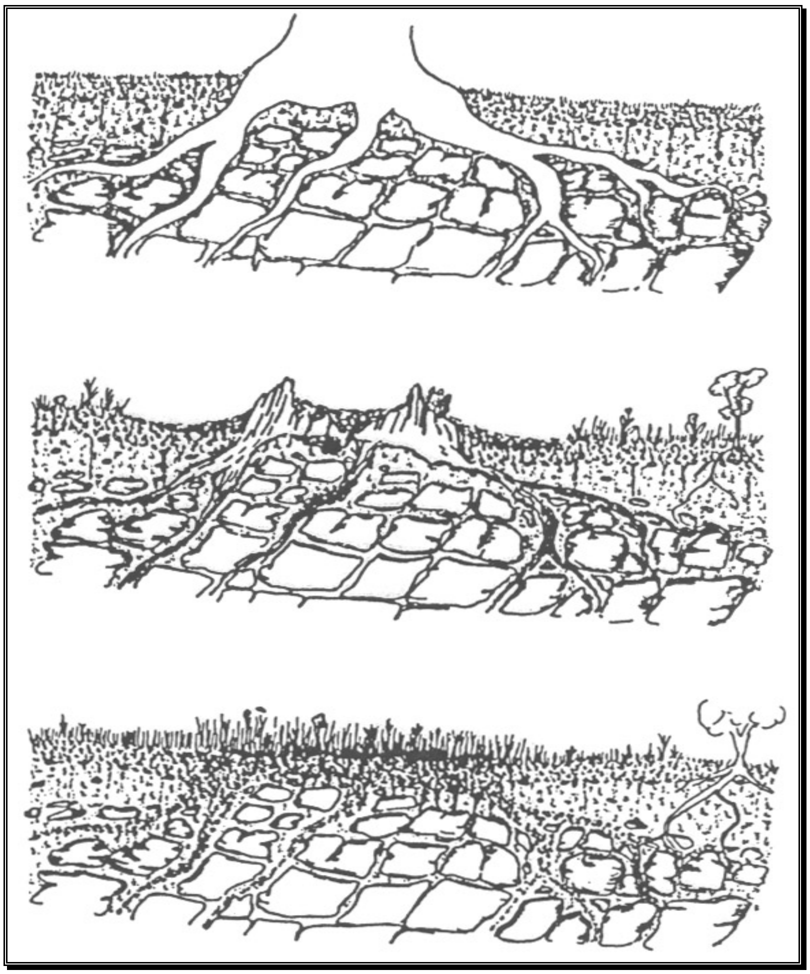

Figure 10.8 Infilling of Decaying Root Channels (Lutz and Griswold 1939**)**

Tree throws may be difficult to detect in certain conditions (Langohr 1993). These conditions include areas with loose and fragmented earth (i.e., usually characterized by trees with very shallow rooting systems or trees on slopes); older tree throws with little or no traces of the soil horizons; tree throws in areas where the soil had weakly developed stratigraphy prior to the throw; and intense pedogenetic processes immediately after tree throw (e.g., bioturbation by worms and larger burrowing animals). Artifact distributions have been used as tree throw indicators, when soil conditions (i.e., sandy soils) are inconclusive (Crombe' 1993). In the case of a northern Belgium study, the general time frame of the tree throw occurrence was identifiable through the presence or absence of Mesolithic artifacts. The cultural occupations of the site occurred prior to most of the tree throws. The artifact distributions in these tree throws concentrated on the leeward side of the throw (Crombe' 1993).

Studies of the longevity of pit/mound pairs have involved the use of several different methods of age estimation and are usually based upon one or more of the following types of evidence: (1) relation of the pit/mound pair to a known natural disaster (i.e., tornado, hurricane, or volcanic eruption) in the area (Held and Bryant 1989, in Schaetzl et al. 1990); (2) soil development within pits in combination with careful study of pit/mound morphology (Denny and Goodlett 1956; Lyford and MacLean 1966); (3) dendrochronologic age estimates of trees growing on mounds or within pits (Veneman et al. 1984); (4) estimation of increased tree growth surrounding pit/mound pairs (Foster and Reiners 1986 in Schaetzl et al. 1990; Henry and Swan 1974); (5) measurement of infilling and root-plate deterioration processes (Small 1987); and more recently (6) radiocarbon dating methods applied to organic materials buried within pits (Schaetzl and Follmer 1990).

Estimates of pit/mound longevity vary greatly, frequently due to regional differences in climate, sediment characteristics, and area of initial disturbance. In humid, tropical environments, the rate of infilling can be extremely rapid, removing all traces of original pit/mound microtopography within five to ten years (Putz 1983). At the other extreme, studies of sandy mounds in Michigan suggested they were approximately 2400 years old based on C14 evidence (Schaetzl and Follmer 1990). This estimate stands in sharp contrast to those produced by alternate methods applied to these same mounds, which suggested a mean age of 500 years or less (Beatty and Stone 1986; Swanson et al. 1982). Regardless of the methods used in age determination, Schaetzl et al. (1990) caution that age estimates of extant mounds do not necessarily represent maximum longevity, primarily due to environmental and other factors involved in their degradation.

SUBSURFACE TREE MORPHOLOGY STUDY

Despite the on-going controversy surrounding the excavation and interpretation of these subsurface anomalies, few archaeologically-oriented studies of tree throws have been conducted in Delaware and surrounding areas (Mueller and Cavallo 1995; Thomas 1982; Thomas and Payne 1981). In order to aid in the interpretation of the range of environmental and cultural processes that have led to the complex archaeological patterning within the State of Delaware, an experimental subsurface tree morphology study was undertaken in conjunction with excavations at Hickory Bluff. This study was conducted on-site to provide a data set that would be comparable to excavated features encountered during concurrent archaeological investigation.

Hickory Bluff provides a unique opportunity to investigate the tree throw hypothesis. The western half of the site was unplowed, and tree disturbances in that area had likely retained much of their original configurations. The area was vegetated in mature forest, the tree species likely representative of those occurring on site during the later half of the Holocene. Previous and ongoing work at Hickory Bluff provided ample evidence for the presence of large basin features on site. This allowed for a direct comparison of subsurface configuration of trees with archaeological basins identified within the same pedological and environmental contexts.

Methodology

Prior to the beginning of the investigation, a systematic survey of the entire project area was conducted in order to inventory all tree related ground disturbances potentially available for study. Depressions and hollows created by rotting tree stumps or tree throws and standing, decomposing tree stumps were included for consideration. Seventeen examples were chosen for investigation. The sample was chosen to incorporate a variety of tree sizes and different species. Tree stumps were measured 20 cm from the soil-stump boundary in order to determine size category. Size categories were small (<40 cm), medium (40-80 cm), and large (>80 cm). The majority of these specimens were located within the unplowed portion of the site, both on the terrace (bluff) top and its western slope. Examples within the eastern, plowed portion of the site were also included in order to provide comparative material for features in similar disturbed contexts. When extant wood was present, it was identified to species level, when possible, by archaeobotanist Justine Woodard McKnight.

Ground surface disturbances caused by the decomposition of stumps, or by tree throws, were first bisected to obtain a profile for direct comparison with bisected cultural features. The remainder of the ground surface disturbance was then removed using additional units. Standing, decaying stumps were simply bisected with a trench large enough, both horizontally and vertically, to determine the full extent and nature of the tree's sub-grade configuration.

Data collection methods were modeled on those used in the archaeological investigations in order to obtain comparable data sets. Excavation of tree throw depressions and decomposing stumps were conducted utilizing arbitrary 10-cm levels within visually discernible strata. All soil disturbed was removed as "feature fill," leaving the undisturbed surrounding soils in place. During the course of the excavation, a succession of planview maps was generated and extensive photo-documentation was undertaken. When the "feature fill" had been fully removed, final photographs were taken and contour maps of the resulting excavation were generated at appropriate (2.5-10 cm) intervals. Whenever archaeological features were encountered during experimental excavations, they were carefully recorded and removed according to site methodology, noting the impact of the tree's intrusion on the feature when possible. If the tree did not significantly disturb the cultural feature, the remainder of the tree was removed while leaving the feature in situ.

Each of the trees excavated at Hickory Bluff were separated into one of the following three categories: standing, partially decayed stumps, depressions caused by stumps completely decayed in situ, and tree throws. Standing, partially decayed stumps were chosen to constitute the majority of the study sample as these were shown to be the most common type of tree related ground disturbance on the site. The second category of tree related ground surface disturbance consisted of depressions left in areas in which the tree/stump had apparently fully rotted away. These were identified as roughly circular to ovoid depressions on the ground surface. Of the seventeen trees originally identified for bisection (BX), two were deleted from the study during early stages of their investigation. BX 11 was a slight surface depression about 10 cm deep and of unknown origin. BX 13 exhibited evidence of recent soil disturbance and inclusions of modern debris. Both disturbances were deemed not to represent tree locations and were deleted from the study sample. A single tree bisection, designated BX 18, was added to the study in conjunction with analysis of the archaeological excavations. The BX 18 designation was applied to a large, living oak tree that had been sectioned by an archaeological block excavation.

In addition to archaeologically documenting tree related disturbances at Hickory Bluff, other observations were incorporated into the study. These included: three tree throws at the Puncheon Run Site located on the west side of the St. Jones River, across from Hickory Bluff; the archaeological documentation of a tree throw at the Sandom Branch Site Complex (7NC-J-227/7NC-J-228), located about 18 miles north on a small tributary of Blackbird Creek; and monitoring of the tree and stump removal undertaken at Hickory Bluff subsequent to completion of archaeological excavation.

Standing or Partially Decayed Stumps

A total of nine stump features were investigated (BX 2, BX 4, BX 6, BX 9, BX 10, BX 12, BX 14, BX 15, BX 16).

BX 2

This was a small (25 cm) pine, probably in the yellow/hard pine group, that was bisected with two 1 m^2 units that removed the west half of the tree (Figure 10.9). The root mass remained intact with significant amounts of fresh wood present. In profile, the stump retained quite a bit of heartwood, indicating that the tree had not been dead for very long. The eastern profile displayed a broad central tap root with two smaller roots extending diagonally downward from its base. The tap root extended to a depth of 70 cm and measured approximately 10 cm across at its terminus. Soils immediately adjacent to the roots contained small, concreted bits of soil (1-3 cm), and a darkened, organically stained matrix was variably present around the outer edges of each root, extending no more than 1 cm in any direction. The A- and E-horizons remained intact, showing almost no evidence of intrusion, and all roots terminated just above the E/B-horizon transition.

BX 4

This large decomposing red oak stump (*Quercus* sp.) measured 90 x 120 cm. The west half of the stump was removed using two 100 x 80 cm units. The root mass was encountered at three relatively discrete horizontal levels, measuring 5 cm, 13 cm, and 28 cm below the current ground surface and reached a maximum horizontal diameter of 1.6 m (Figure 10.10). In profile, roots remained clearly defined by papery exterior shells filled with decayed organic root matter. The stump remnant penetrated into the subsoil on the north end of the excavation to a depth of 40 cm. The transition between the A- and E-horizons was heavily disturbed by root intrusion, resulting in soils with a high degree of mottling (>50 percent). The B-horizon was completely unaffected.

Figure 10.9 Tree Bisection BX 2

Figure 10.10 Tree Bisection BX 4

BX 6

This stain was approximately 50 cm in diameter, amorphous in shape, and was probably the remains of a cedar stump (Figure 10.11). It was bisected using a 1 x 3 m trench. A rodent hole and tunnel traveling toward the stump were visible at the surface. Large areas of root activity were mapped at the top of the plow zone and E-horizon. A large stain, 60 cm in size, at a different orientation, was mapped at the top of the reddish subsoil. This was excavated as part of the root ball, but in profile was viewed as a separate stain. The stump itself forced portions of the A-horizon into the underlying matrix with concreted soils in the vicinity of the wood. The total depth of this excavation was 72 cm.

Figure 10.11 Tree Bisection BX 6

BX 9

This stump was a small (25 cm) cherry (*Prunus serotina*) rotting on the surface. The west half of this stump was removed utilizing a 1 x 2.5 m trench. The root mass was completely decayed and was identified by dark organic staining that retained no traces of wood. Root stains radiated horizontally from the central root mass at natural soil transitions (Figure 10.12). The profile showed a roughly circular organic stain in the area of the decayed root mass that measured approximately 25 cm in diameter. The A-horizon soils had been dragged downward by root development and decay into the sediment below, creating a wide, shallow lens (10 cm deep and 1 m in diameter) of organic soil intruding into the upper portions of the E-horizon. B-horizon soils were not penetrated by the root mass. The entire excavation filled a wide, shallow depression that measured over a 1 m area and was excavated to a depth of 58 cm below datum (bd).

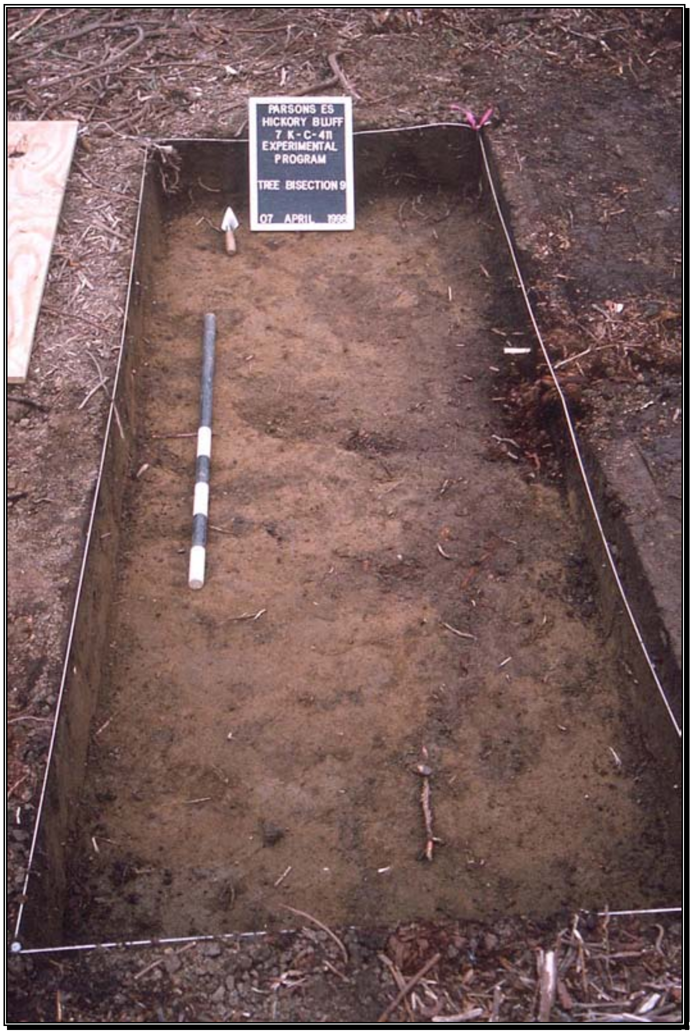

Figure 10.12 Tree Bisection BX 9

BX 10

This medium (40 cm) red oak stump (*Quercus* sp.) was located on the western slope of the landform (Figure 10.13). It was bisected using a 1 x 3 m trench to remove the northern half. Roots, which were partially decayed, radiated diagonally, vertically and horizontally from a central area measuring up to 1.5 m wide in profile. Disturbance to surrounding soils was minimal and localized around the main body of roots that had been anchored within A- and E-horizons. Minor areas of soil concretions were found immediately below the rotting stump and around larger decaying roots. Impact to B-horizon soils was not observed.

Figure 10.13 Tree Bisection BX 10

BX 12

This large (90 cm) red oak stump (*Quercus* sp.) was bisected using a 1 x 3 m trench that removed the southern half of the decaying stump and root-disturbed soils (Figure 10.14). In profile, the root disturbance occurred in a discrete area approximately 2.5 m wide. Impact to the E-horizon soils, however, appeared to be minimal. The presence of decayed roots was betrayed by diffuse organic staining seen at the upper portions of the E-horizon. Individual roots could be traced radiating outward from the central root mass beginning approximately 10 cm into E-horizon soils and decreasing in size and number with depth. B-horizon soils were penetrated by five individual roots resulting in a slight depression at the E/B-horizon interface. The root ball was bisected twice to determine if it possessed a taproot. None was recorded.

BX 14

This bisection was located about 8 m from the St. Jones River's edge in an area that had been impacted by a small historic borrow pit. A- and E-horizons were both depleted and very sandy. Subsoil consisted of sand with medium and small gravels. A large standing pine stump (probably in the yellow/hard pine group) was bisected along the east-west axis, utilizing a 1.75 x 2 m block (Figure 10.15). The stump measured approximately 80 cm across at ground surface and disturbed an area about 2 m in diameter with a depth of 78 cm bd. Although most root disturbance was restricted to a shallow, irregular shaped area around the stump, horizontal extensions of this disturbance into the surrounding subsoil were noted.

Figure 10.14 Tree Bisection BX 12

Figure 10.15 Tree Bisection BX 14

BX 15

This was a large (50 cm) partially decayed white oak stump (*Quercus* sp.) bisected on a north-south axis with a 1 x 2 m trench (Figure 10.16). Individual roots were largely intact (undecayed) and radiated both diagonally and vertically from the central core. The stump disturbed a subsurface area 1 m in diameter to a depth of 52 cm bd. A TAS cluster (Feature 162) was encountered in the northernmost unit approximately 15 cm below modern surface. Detailed maps were drawn and the feature was left in place in the northern half of the 1 m unit. Feature 163, a second TAS cluster was identified originating 5 cm below Feature 162. Both features were fully documented. Soil disturbance was minimal in all horizons, restricted to the 1-2 cm immediately surrounding each individual root. Several small roots (<3 cm in diameter) intruded into B-horizon soils, but disturbance surrounding each was less than 1 cm. The disruptive effect of the root growth on TAS placement and configuration was difficult to assess. However, based on the individual artifacts' vertical positions, translocation is not thought to have been extensive. In several instances, roots were observed growing around individual TAS artifacts rather than apparently having displaced them.

Figure 10.16 Tree Bisection BX 15

BX 16

This large (85 cm) partially decayed red oak stump (*Quercus* sp.) displayed characteristics of both standing stumps and tree throws (Figure 10.17). It had partially fallen before snapping, approximately 40 cm from its base. The tree trunk remained lying towards the east, beside the decaying stump. The base of the tree began to pivot on an east-west axis, bringing up a small mound of A- and E-horizon soils on the western side. In excavated (exposed) profile, the root mass remained clearly defined. Larger roots were present as papery outer husks filled with decayed root matter, whereas smaller ones were discernible only as organic soil stains. While the partial tree throw appeared to have disrupted a portion of the underlying profile, the subsurface disruptive effects of the actual tree growth appears to have been minimal and restricted to localized organic staining around larger root masses. Soils beneath the central core of the root mass appeared extremely concreted. Two thermally altered stone (TAS) features were identified in this bisection. Features 182 and 189 were encountered approximately 15 cm below the surface near the top of the E-horizon and were separated by two large, relatively intact roots. The western and eastern units were bisected, leaving half of each feature in situ.

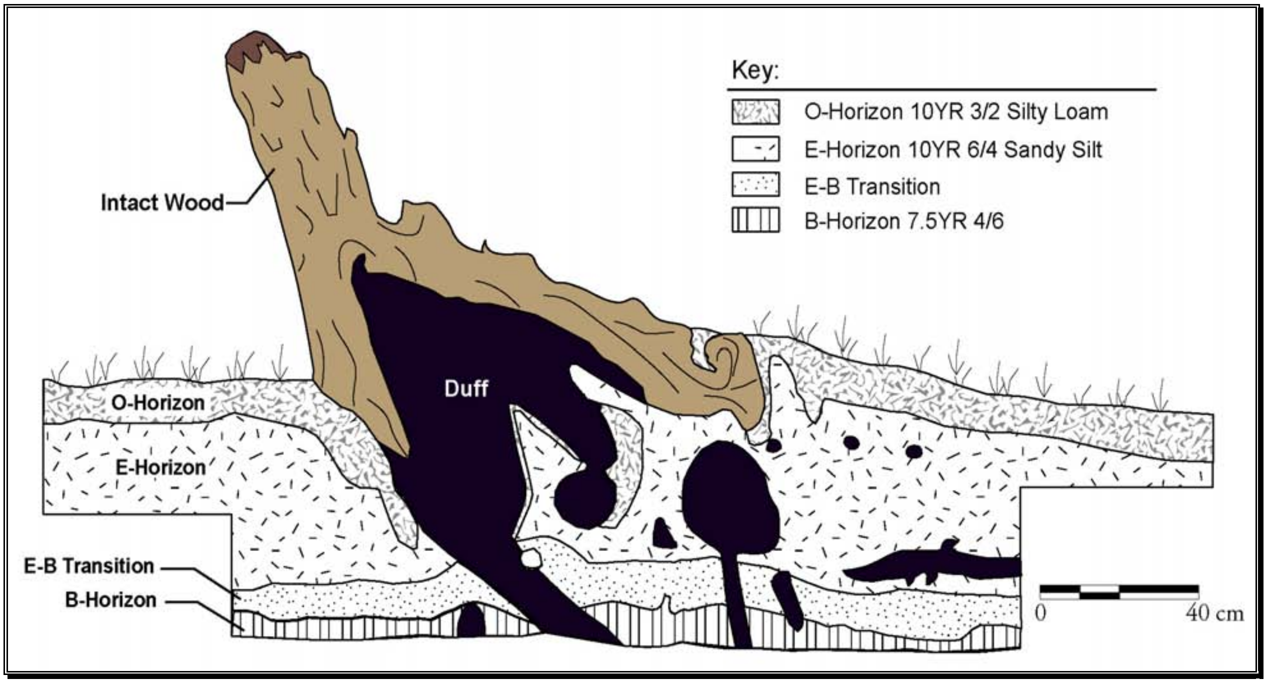

Figure 10.17 Hickory Bluff BX 16 Profile

Stump Depressions

Two tree depressions resulting from the decomposition of tree stumps were investigated (BX 1 and BX 8).

BX 1

This circular depression measured 1.3 m in diameter and 15 cm deep at the surface (Figure 10.18). The entire depression was removed using a 2 x 2 m block. The north half of the depression was removed first in order to obtain a bisection profile. A roughly circular, charcoal-flecked patch of A-horizon soils intruded into the E-horizon. This conformed closely in size, shape and location to the surface depression, and may have been caused by soil eroding into the void created by the decomposition of the tree stump and root ball. Except for the presence of charcoal flecking within A-horizon sediments, soils were homogenous and compacted. The area of intrusion was removed in 10 cm levels, resulting in a basin-shaped excavation approximately 1.15 m wide x 35 cm deep. The sides were relatively smooth, although some surface irregularities were noted. Following excavation of the charcoal-flecked A-horizon soils, the surrounding homogenous E-horizon matrix was removed. At the E/B-horizon transition, a roughly circular disturbance was present, located almost directly below the surface depression. This area was filled with silty E-horizon sediments with a central core of mottled soils presumably pushed down by root growth. When disturbed sediments were removed, a roughly basin-shaped area (80 cm wide x 30 cm deep) remained. Irregularities and indentations, apparently voids left behind by the decomposition of the root system, punctuated the bottom and sides.

Figure 10.18 Hickory Bluff BX 1 Excavated Planview

BX 8

This circular depression was located at the western edge of the site on a modest slope associated with the bluff edge. The depression measured approximately 90 cm in diameter and was 12 cm deep from the surface (Figure 10.19). It was excavated within a 1 x 2 m block. The void apparently was created when the stump and root ball decomposed and subsequently filled in with compact, homogenous A-horizon soils. These soils interfaced with the underlying E-horizon, forming a conical shaped feature measuring 35 cm wide at the top and 30 cm deep. B-horizon soils did not appear to have been affected by the root system. Two large, completely rotted roots were located near the area of disturbance, but neither of these clearly emanated from the root ball area.

Figure 10.19 Tree Bisection BX 8

Tree Throws

The third group of tree related ground disturbances consisted of apparent tree throws, or depressions caused by the uprooting of trees, and included BX 3, BX 5, BX 7, and BX 17. BX 5 and BX 17 represented confirmed (obvious) tree throws, while BX 3 and BX 7 were suspected tree throws.

BX 5

The stump of the fallen tree with attached roots was still lying adjacent to a roughly circular, partially infilled depression where the stump pulled out of the ground (Figure 10.20). It was investigated using a 2 x 2 m block. The stump was approximately 20 cm in diameter at the base. The attached root mass and adhering uplifted sediments measured approximately 80 cm in diameter. The depression caused by uprooting measured approximately 90 x 110 cm and was more than 25 cm deep at the center. A-horizon development was almost nonexistent within the ground surface disturbance itself. When surrounding A-horizon soils were removed, an ovoid area of loosely packed mottled A- and E-horizon soils was visible within the compact, homogenous E-horizon surrounding the area of ground disturbance proper. The loose nature of soils and the paucity of organic buildup within the depression suggested that the downing of the tree was a fairly recent event. When mottled A- and E-horizon sediments were removed, the void remaining was basin-shaped and shallow, measuring approximately 1 m wide x 10-20 cm deep, with an uneven bottom contour. The B-horizon soils were not extensively penetrated by the root system and remained relatively unaffected by the downing of the tree. The entire excavation extended to 70 cm bd. Feature 92, a large irregular basin, was identified in unit N375 E662, subsequent to the removal of the extant tree disturbance.

Figure 10.20 BX 5 Stump and Depression

BX 17

This large (81 cm diameter) black cherry tree (*Prunus serotina*) was discovered lying approximately 6 m from the depression created as it fell (Figure 10.21). The ground surface disturbance caused by the uprooting of the tree was clearly visible approximately 6 m to the northwest, with two visible tire tracks on either side of the depression. The tree had most likely been uprooted mechanically, or pushed from its original position. A large portion of the root ball remained intact above ground at the base of the trunk. Some of the soils that had adhered to the root ball had sloughed to the ground, forming a 98 cm high x 2.5 m wide mound on the ground surface. The above ground portion was removed first, each unit individually, in order to obtain a profile view. Soils within both the mound and the depression were characterized by a high degree of soil mottling resulting from the mixing of soil horizons. Bisection of the mound revealed a somewhat ovate bottom contour that was very irregular, with one deep central section intruding into the B-horizon, positioned close to the fulcrum point of the tree throw.

Figure 10.21 BX 17 Stump and Depression

BX 3

This surface depression was ovoid in shape, measuring approximately 1.3 x 1 m, and 10 cm deep at the surface (Figure 10.22). It was investigated using a 1 x 2 m block. After the A-horizon was removed, an oval area was visible at the top of the E-horizon where organic debris had collected at the base of the ground surface disturbance. When this depression was bisected, the profile clearly showed horizontal banding of lighter soils within the darker, organic fill. After surrounding E-horizon sediments were removed, it was evident that E-horizon soils had been pushed down into the B-horizon in a localized area by growth of the root system. There was a central area of heavily mottled sediments within this depression. When these soils were removed, the resulting void was shallow, with an irregular outline and bottom contour due to root growth and disturbance. A TAS feature (Feature 83) was discovered at the A/E-horizon interface immediately to the east of the excavated ground surface disturbance.

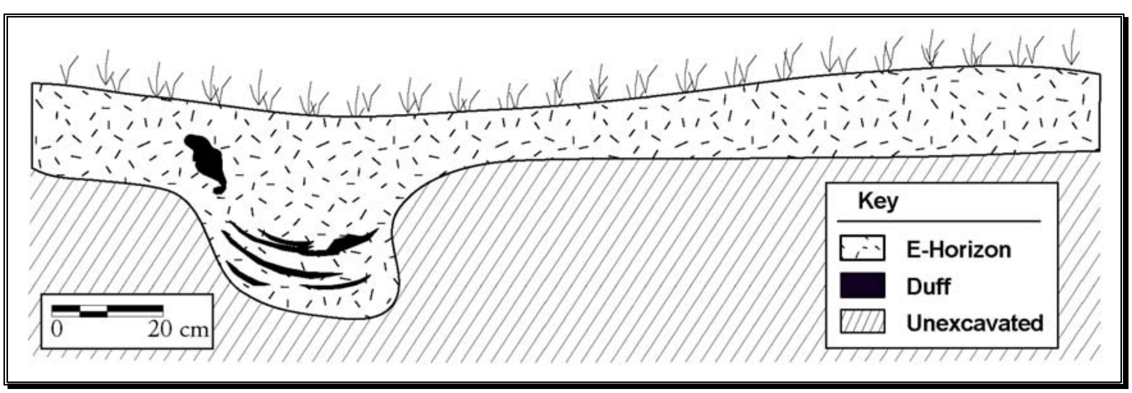

Figure 10.22 Hickory Bluff BX 3 Profile

BX 7

This shallow surface depression measured 110 x 80 cm across and 6 cm deep (Figure 10.23). It was investigated using a 1 x 2 m trench. Upon removal of the A-horizon soils, a roughly circular area of mottled A- and E-horizon soils containing a dense root mat was observed penetrating the surrounding E-horizon. Removal of these soils showed the ground surface disturbance to have a deeply rounded profile. The greatest density of the fine root mat was located at the base of this depression. After removal of the undisturbed E-horizon, it became apparent that some E-horizon soils had been introduced into the underlying B-horizon sediments. Removal of the intrusive E-horizon matrix produced a deep basin that mimicked the above mottled intrusion. The outline and bottom contour of the basin were highly irregular. In profile, the disturbance was deep (50 cm) and steep sided, suggesting a large taproot.

Figure 10.23 Tree Bisection BX 7

Living Tree Bisection

BX 18

A living tree was bisected during the course of an archaeological block excavation (Figure 10.24). The specimen was a young mature Black Oak *(Quercus velutina*) approximately 35 cm in diameter. The wall of the excavation unit neatly fell at the very edge of the tree's trunk mass. Observations of the exposed unit profile proved to be instructive in assessing the actual undisturbed below grade configuration of a living tree. The below ground mass was surprisingly limited even for mature trees possessing substantial trunk size (Figure 10.24). The trunk mass essentially terminated at about grade level (base of A-horizon). The trunk flared just above grade level at the points that major roots begin to extend outward. These larger root members extended horizontally just below the humus. A few individual roots were encountered during excavation, growing downward from the base of the trunk. However, when observed in two dimensions only (profile view), areas as little as 20 cm directly below the tree appeared to be completely unaffected.

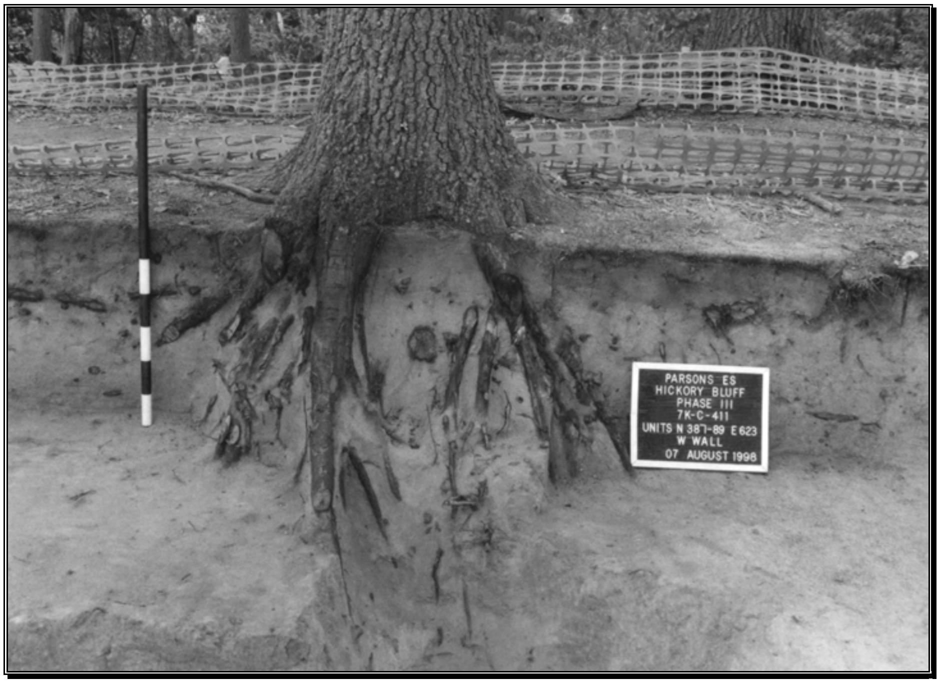

Figure 10.24 Hickory Bluff BX 18 Profile

Treethrow Observations at the Puncheon Run Site and Sandom Branch Site Complex

In addition to observations made on Hickory Bluff, three modern tree throws were documented at the Puncheon Run site. These tree throws were photographed, and planviews and profiles of the ground surface disturbances were recorded when possible. All trees were identified to genus or species.

The largest of the three downed trees at the Puncheon Run site was a fully mature yellow poplar (*Liriodendron tulipifera*) with a bifurcated trunk. It was uprooted in June 1998 during a severe storm that brought wind gusts up to 80 mph. The depression created by the uprooting event was D-shaped in plan and measured 4.5 x 2.3 m (Figure 10.25). Though the tree was far larger than any of those bisected at Hickory Bluff, the maximum depth of the ground surface disturbance was only 70 cm. A small tap root was noted near the center of the root mass, nearly obscured by attached sediments. The basal contour of the disturbance was irregular. As the event was quite recent, infilling processes had not redeposited significant amounts of sediment within the ground surface disturbance.

Figure 10.25 Puncheon Run Site Downed Tree

The second Puncheon Run tree throw was also a large yellow poplar (*Liriodendron tulipifera*). Some soil had sloughed into the ground surface disturbance but a significant portion of the displaced soil remained attached to the extant, above surface root mass (Figure 10.26). This ground surface disturbance had a very irregular planview outline and profile. Maximum dimension in plan was 6.0 m with minimum dimension recorded at 1.5 m. Maximum depth of the ground disturbance was noted as very shallow, although its exact extent was not recorded.

Figure 10.26 Puncheon Run Tree Throw #2

The third tree had fallen downslope into the St. Jones River, and only a portion of the root mass was visible (Figure 10.27). The tree throw was older, as much of the ground disturbance had been infilled by slopewash and other processes. A very shallow depression was still evident immediately adjacent to the existing root mass, but little sediment remained attached to those roots, apparently having mostly sloughed back into the ground disturbance/cradle.

Figure 10.27 Puncheon Run Tree Throw #3

Archaeological documentation of a recent tree throw also was undertaken at the Sandom Branch Site Complex (7NC-J-227/7NC-J-228), located north of Smyrna, New Castle County, Delaware. This tree throw was observed during excavations at the Sandom Branch Site Complex and it was determined that excavation of the units associated with the tree throw would be beneficial to the overall study. The tree throw was investigated using two 1 x 1 m units that bisected the ground disturbance on a north/south axis. The specimen was a mature red oak (*Quercus* sp.) that had recently fallen. It appeared to have been alive when it fell, as evidenced by the presence of withered leaves on the branches. The upturned root ball measured approximately 2 m in diameter (Figure 10.28). The ground disturbance was D-shaped and was 10 to 15 cm deep. The water table was within 50 cm of the surface and did not allow for complete excavation of the units. The soil was a loose sandy loam and was saturated.

Figure 10.28 Sandom Branch Tree Throw

Monitoring Observations

Parsons staff were present during tree removal from Hickory Bluff at the start of project construction (Figure 10.29 and Figure 10.30). A large track hoe was employed to excavate and remove cut stumps. This allowed for the opportunistic examination of the below ground configuration of a large portion of the mature tree specimens that had been standing on Hickory Bluff. The major radiating near-surface segments were severed by the track hoe blade and left in situ. When the tree was removed from the ground, an extensive system of fine diameter roots was observed remaining attached to the main body of the stump. The majority of these were less than one inch in diameter. These small diameter roots comprise major portions of a tree's root system and are critical for both anchorage and transporting water and nutrients (Figure 10.30). In the event of a tree throw, these roots were typically observed to shear off near the base of the stump. Such root systems, left in place, either after being severed during a tree throw or after a tree naturally dies, are likely to simply degrade without leaving any appreciable physical traces.

Summary of Findings

The Subsurface Tree Morphology Study at Hickory Bluff provided several important insights. Perhaps the most salient of these was the documentation of how little actual below grade mass even a large tree possesses relative to its overall size. This understanding has considerable implications both for the preservation of near surface archaeological contexts and basin feature formation. The limited physical extent of the below grade tree configuration is borne out by a variety of observations. Stump crater excavation repeatedly suggested that extensive root disturbances associated with a tree location were relatively shallow. With the exception of individual tap roots, disruptions of the soil profiles were rarely seen to penetrate the E/B-horizon interface, which typically lay at a depth of 40 to 50 cm below surface. Documentation of tree throw morphology also appeared to demonstrate that the major components of the tree root systems extended outwards just under the surface. This observation was evidenced by the shallow form of the tree throw related ground disturbances documented at Hickory Bluff, the Puncheon Run site and the Sandom Branch Site Complex. The same phenomenon was demonstrated by the profile of the live tree, BX 18.

Figure 10.29 Tree Stump Removal at Hickory Bluff Illustrating the Root Ball

Figure 10.30 Tree Stump Removal at Hickory Bluff Showing the Fine Diameter Roots

EXPERIMENTAL FEATURE DEGRADATION STUDY

Both cultural and natural forces work in concert to form and shape the archaeological record. Despite the critical importance of these interactions, most archaeologists have fairly coarse conceptual understanding of the sequence of events and changes that occur as a ground surface disturbance is transformed into an archaeological entity. The experimental feature degradation study was initiated to observe and document how a variety of feature morphologies degrade and infill through time, and how these processes may lead to particular archaeological patterning. Eight experimental features (XF) were excavated in February 1998 on the southern periphery of Hickory Bluff. These experimental features were constructed in forms replicating archaeologically documented feature types. Changes to the features and the conditions under which these changes occurred, were carefully monitored and recorded. The observational study reported herein was conducted from February 1998 through April 2001. The experiments remain available for future study.

Methodology

The experimental excavations were constructed along a partially cleared east-west strip along the southern periphery of the Hickory Bluff project area (Figure 10.31 and Figure 10.32). The experimental features were placed in a staggered pattern, approximately 4 m apart, to facilitate easy access in and around them (Figure 10.33). Permanent rebar datums were driven into the ground adjacent to the individual features and were used for recorded measurements (Figure 10.34).

Figure 10.31 Experimental Feature Degradation Study Area Prior to Excavation, Looking East

Figure 10.32 Experimental Feature Degradation Study Area Post-Excavation, Looking West

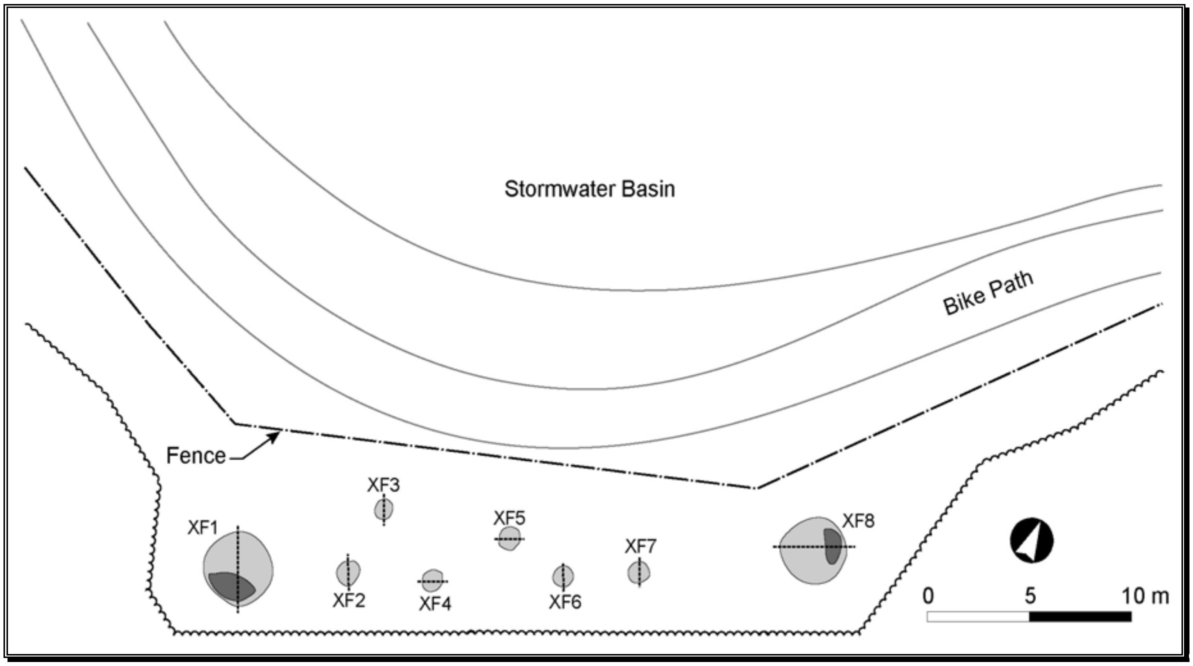

Figure 10.33 Experimental Feature Degradation Study Area Plan

Figure 10.34 Experimental Feature Degradation Study, Placing Datum at XF 8

The experimental excavations were designed to replicate archaeological feature types previously documented in Delaware. These entailed three morphological types: 1) large bi-level features replicating the pit house configuration (Custer and Silber 1995) typified by a very wide shallow portion or "living floor" with a steep-sided, flat-bottomed, D-shaped basin or "sub-basement" set in one end (Figure 10.35); 2) deep circular basins with conical profiles (Figure 10.36); and 3) circular basins with shallow bowl-like profiles (Figure 10.37) (Table 10.1). In all, two large bi-level features (XF 1 and 8), four deep conical features (XF 2 , 4, 5, and 6), and two shallow bowl-shaped features (XF 3 and 7) were constructed.

Figure 10.35 Large Bi-level Feature XF 1

Figure 10.36 Deep Circular Basin XF 2

Figure 10.37 Shallow Bowl-shaped Basin XF 7

Specific variables were applied to the experiments (Table 10.1). These entailed, purposeful back filling of the features versus being left open, and the removal of excavated soils from the area as opposed to the soil being placed near the feature orifice. Six experimental features (XF 1-3, XF 6-8) were left open and two features (XF 4 and XF 5), both deep circular basins, were immediately backfilled. Experimental features XF 1, XF 2, and XF 3 had the excavated soil removed from the feature area, while XF 6, XF 7, and XF 8 had the soil left in situ. The five westernmost pits (XF 1 through XF 5) were located in an area subjected to almost continuous sunlight during the course of the day, while the three eastern features were situated in a much more shaded environment.

Soils and soil conditions within the experimental area essentially mirrored those described for the archaeological site (Section 6.0). The experimental area had been plowed during modern or recent historical times. The area had been fallow for some time and had partially reverted to a young forest, resulting in the development of a thin forest humus overlying the plow zone. Soils were uniformly sandy (loamy sand) with an E-, BE-, B-horizon sequence present below the plow zone (Ap-horizon). Columbia Formation (Fm.) sands and gravels (C-horizon) comprised the basal stratum. These Columbia Fm. deposits were noted lying closer to the surface at the eastern end of the experimental location than at the western end.

Both qualitative and quantitative observations were recorded for the eight experimental features. Qualitative observations focused on four areas: geomorphology (wall collapses and slumping), hydrology (standing water, ice), floral intrusion, and faunal intrusion (animal burrowing and entrapment). Weather observations were also recorded as part of the study. At monthly intervals, the depths of the experimental features were recorded utilizing the permanent datum points. Photographic documentation provided sound visual evidence of the depositional changes and was employed minimally on a weekly basis. From February 27 through September 14, 1998, observations were recorded for every weekday, weather permitting. Daily observations were undertaken in the beginning of the study to document what was postulated to be the most dynamic period of degradation, prior to the establishment of vegetation that would stabilize the soils. From September 1998 through December 1999, observations were made on a monthly basis. Additional observations were recorded sporadically from December 1999 to April 2001. Figure 10.31 and Figure 10.32 depict the area at the beginning of this study. Figure 10.38 represents the study in progress and Figure 10.39 is near the end of the period of observation.

Table 10.1 Experimental Feature Parameters

Feature Number	Feature Morphology	Feature Size (m)	Depth (m)	Aspect	Backdirt Status	Backfill Status
XF 1	Large shallow basin w/D-shaped flat bottomed basin on end	3.12 x 2.80 1.88 x 1.12	0.10 1.00	Exposed	Removed	Open
XF 2	Circular w/deep conical base	1.00	0.97	Exposed	Removed	Open
XF 3	Circular w/ shallow rounded base	0.90	0.42	Exposed	Removed	Open
XF 4	Circular w/deep conical base	1.00	1.00	Exposed	N/A	Filled
XF 5	Circular w/deep conical base	1.00	1.00	Exposed	N/A	Filled
XF 6	Circular w/deep conical base	1.00	1.17	Shaded	In situ	Open
XF 7	Circular w/shallow rounded base	0.90	0.37	Shaded	In situ	Open
XF 8	Large shallow basin w/D-shaped conical basin on end	3.16 x 2.24 1.44 x 1.28	0.16 0.73	Shaded	In situ	Open

Figure 10.38 Experimental Feature Degradation Study in Progress, 1998

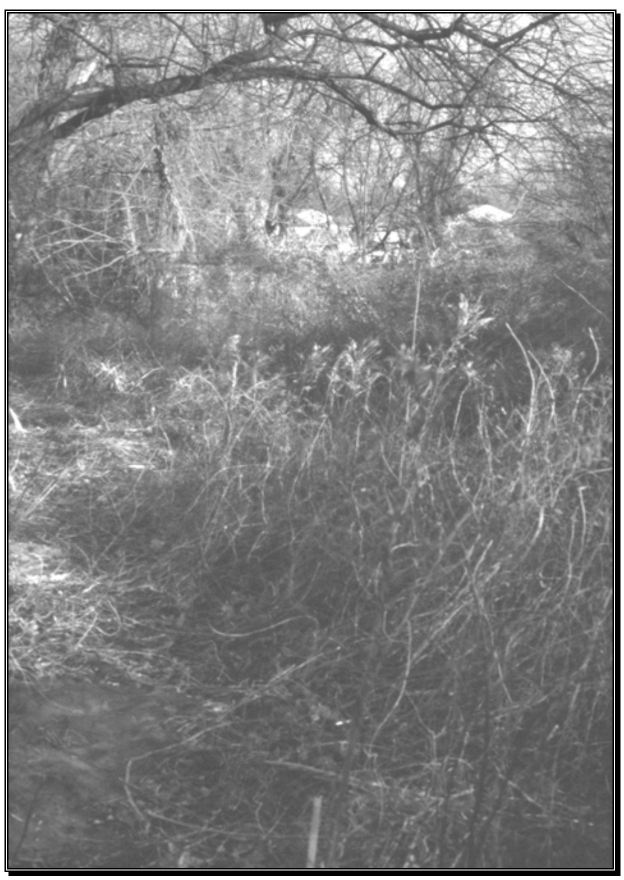

Figure 10.39 Experimental Feature Degradation Study In Progress, 2000, Looking East

In addition to local weather observations recorded on site, temperature, precipitation, and storm event data were collected from the State of Delaware. Daily temperature and precipitation information was compiled for the 1998 portion of this study. Temperature readings for Dover were obtained from the webpage of the Delaware State Climatologist (www.udel.edu/leathers /dov9198). Daily precipitation for Dover was derived from *Climatological Data, Maryland and Delaware* published by the National Climatic Data Center, Ashville, North Carolina. Specific storm events that occurred during this period in Kent County, Delaware were obtained from the National Climatic Data Center webpage (www4.ncdc.noaa.gov/ cgiwin/wwcgi.dll? wwevent ~ storms). Specific peaks in the precipitation data were compared with known storm events and local observation of weather conditions. Freeze/thaw cycles may be implied from the 1998 temperatures recorded for this portion of the study. Only 32 days from February through December 1998 exhibited a daily minimum temperature of 32 degrees or lower (Figure 10.40). Only three days in that time frame had daily maximum temperatures of 32 degrees or lower. Precipitation peaks provided evidence of amount of rainfall and when compared with storm data, indicated the intensity of rainfall (Figure 10.41).

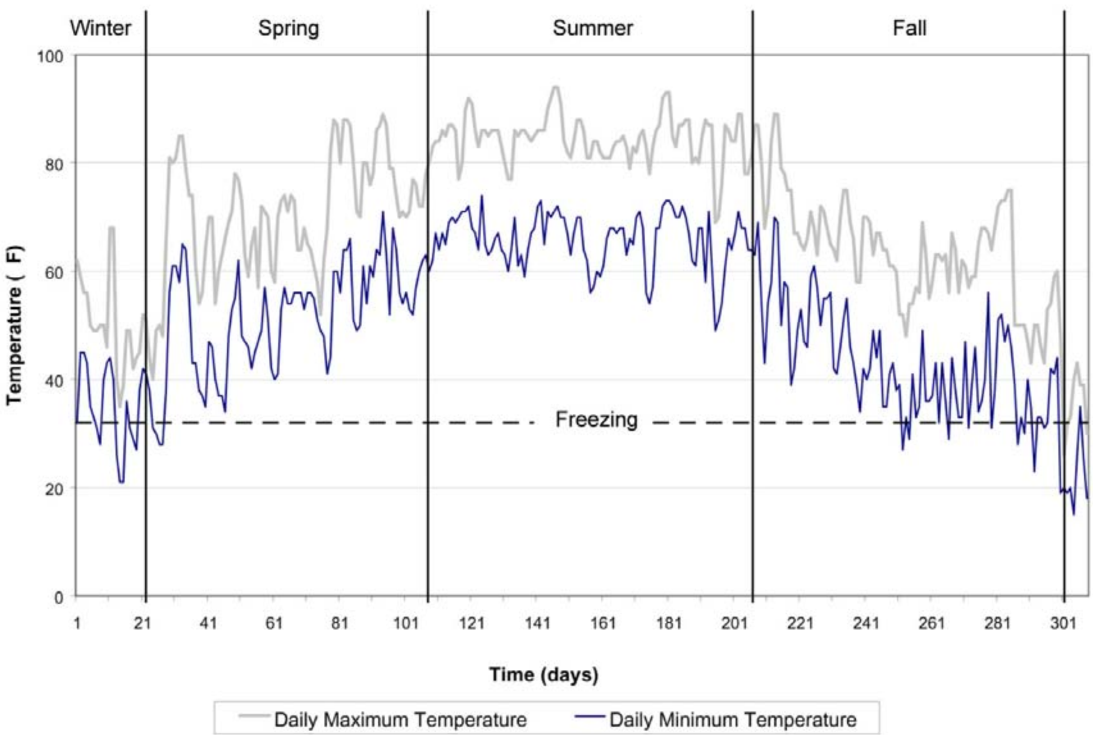

Figure 10.40 Daily Temperature 1998

Experimental Feature Chronology

The general chronology of feature degradation is summarized below for each experimental feature. Detailed observations by date and category are located in Appendix E.

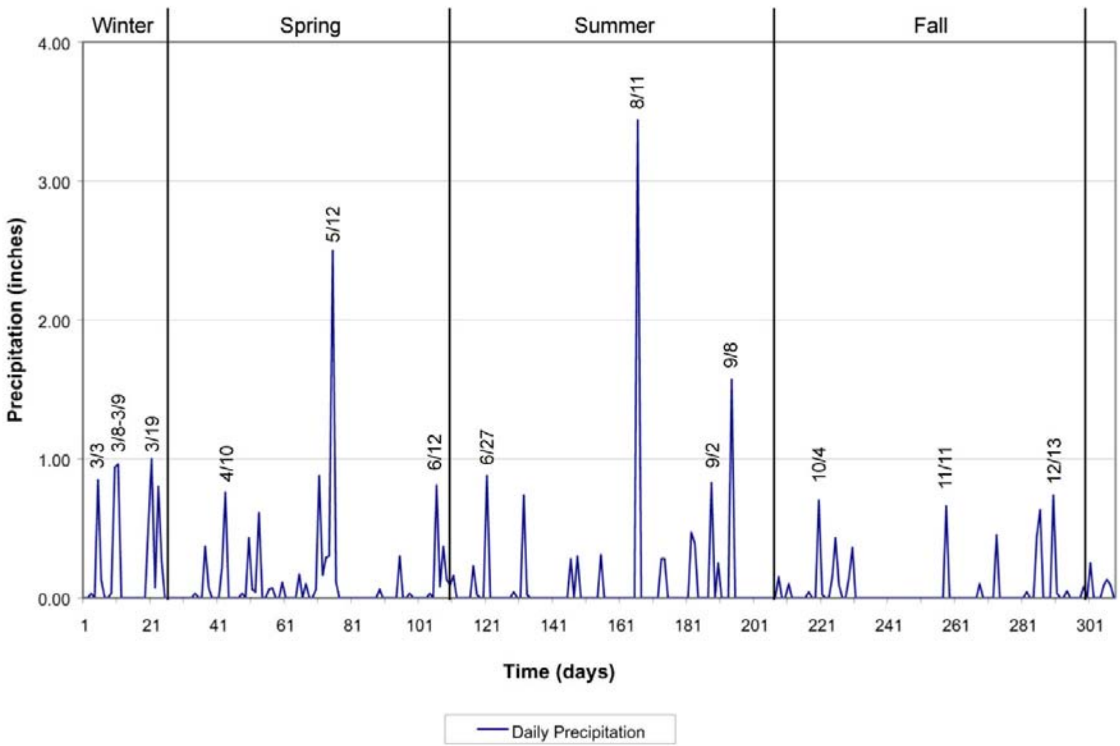

Figure 10.41 Daily Precipitation 1998

XF 1

XF 1 was a bi-level feature replicating the pit house configuration proposed by Custer and Silber (1995). It consisted of a shallow steep-sided, flat-bottomed "basement" or "living floor" area that measured 3.12 m at greatest dimension. A steep-sided, flat-bottomed, D-shaped basin or "sub-basement" was set in one end of the larger feature. This basin measured 1.00 m deep by 1.88 m wide and was excavated into sandy subsoil. The upper level or "living floor" area of this feature was excavated to a depth of 0.10 m and the area was thoroughly trampled after excavation in an attempt to simulate a limited daily usage. The backdirt was removed from the area around XF 1. This feature was located at the western end of the experimental area and was exposed to almost constant sunlight during the course of the day.

Within the first few days after excavation, leaves and small sticks had collected in the feature and worm activity was observed. The bioturbation in XF 1 was concentrated along the edges of the "sub-basement" walls. Less than a week after construction, earthworms tunneling into the floor had created a linear mound of backdirt approximately 15 cm long, 5 cm wide, and 1.5 cm high. Moderately heavy rain left standing water in the deeper "sub-basement" portion of XF 1. In mid March, worm activity decreased, apparently as a result of a series of freezes. The formation of spike ice crystals and resulting minor frost heaving was also observed at this time. This frost action apparently resulted in the observable accumulation of sediments at the base of the "sub-basement." Late March brought a period of rain and a steady infilling of the basins, especially the deeper "sub-basement" portion.

By early April 1998, minor soil slumps were occurring with frequency in the lower portions of XF 1, especially in the “sub-basement” area. This process appeared to be enhanced by soil desiccation and perhaps ongoing earthworm activity. Significant rains occurred in April and the side walls and edges of the basins began to erode in earnest. Small pebbles were washing out of the walls of both of the basins and the side walls were becoming uneven and craggy. At the same time, a large variety of weeds were beginning to take hold in the feature. Progressive vegetative growth was observed later in the spring. This growth appeared to anchor much of the unconsolidated soil in and around the feature. The vegetation itself tended to begin growing more readily on the southern facing portions of the feature, apparently due to greater solar exposure. A sapling was observed growing from the sub-basement in the Spring of 2000, which reached a height of over 2.00 m by the end of the observations.

Earthworms were not the only fauna that appeared to contribute to the degradation of XF 1. A toad was observed in mid-April and it dug a burrow in the bottom of the pit. It disappeared by the first week of May and it is unknown whether it jumped out or was killed and eaten by a predator. A bullfrog was briefly trapped in XF 1, but escaped during observation. In mid May 1998, beehive entrances were constructed, creating holes near the upper edge of the XF 1 “sub-basement” and resulting in small mounds of B-horizon soil in the bottom of the basin. Flies were also observed on the bodies of decaying earthworms in the bottoms of both pits and were likely laying eggs there.

Measurements of depth were taken at two different locations in the XF 1 “sub-basement:” the east end and the center. Incremental filling of the excavation was noted throughout the study (Figure 10.42). Two distinct filling episodes were recorded for August of 1998 and in September 1999. The August 1998 increase was likely the result of a series of heavy thunderstorm rains that occurred during that time. The September 1999 accumulation can be directly attributed to the Hurricane Floyd event (9/16/99).

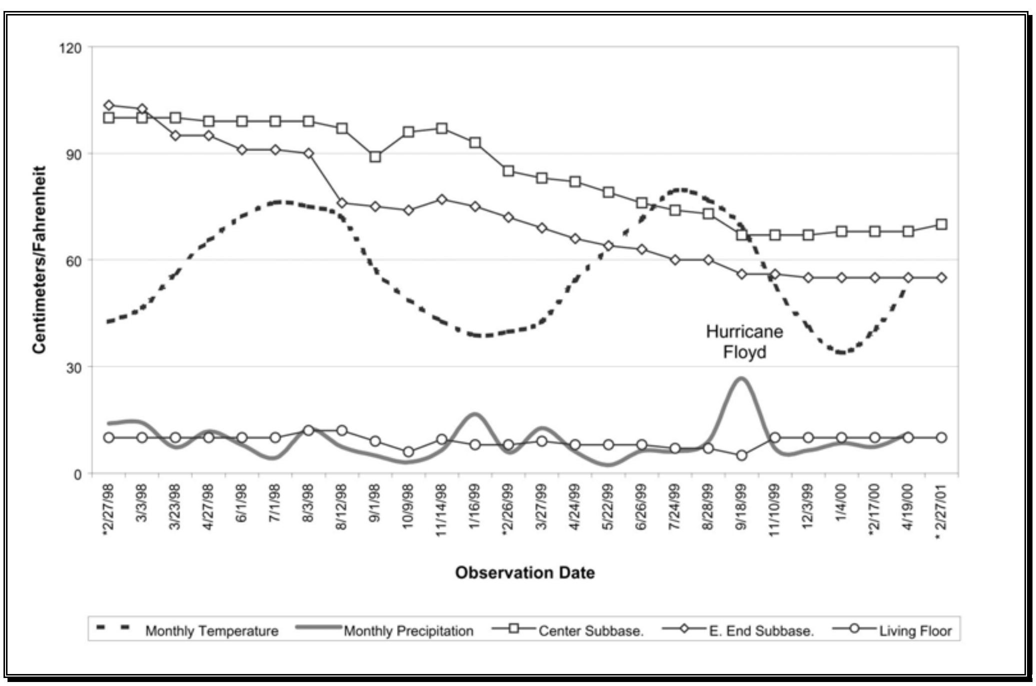

Figure 10.42 Rate of Infilling Compared to Monthly Precipitation and Temperature for XF 1

At the close of the three-year observation period, XF 1 was profiled for comparison with the original profile documentation (Figure 10.43). The comparison of the two morphologies indicated the degree of slumping and infilling noted since excavation and illustrated how the feature shape became less regular and more smoothed. The sharp cuts and planes evident in the initial excavation were weathered and the once steeply sloping walls were more gradually tapered to a rounded, instead of flat, bottom.

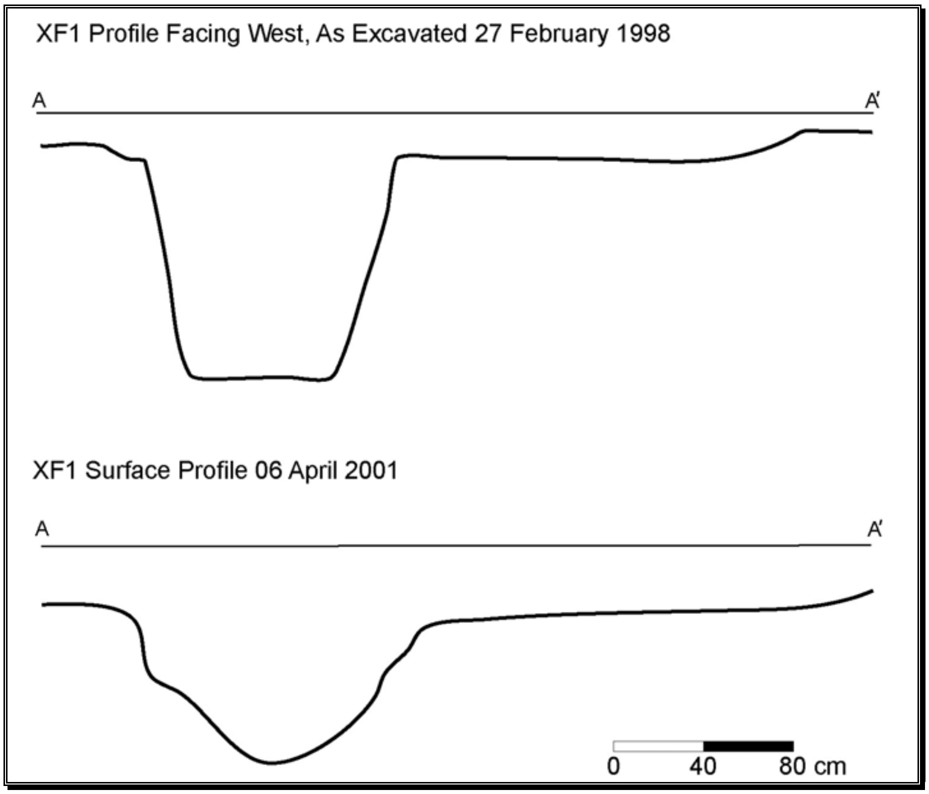

Figure 10.43 Morphological Comparisons for XF 1 over the Course of the Observation Period

XF 2

XF 2 was a deep circular basin measuring 1.00 m by 0.97 m deep. The feature was excavated to a depth at which it penetrated the Columbia Fm. sub-strata. The backdirt was removed from the immediate area of XF 2.

Marked changes began to occur within a week of construction. Rains began smoothing and rounding the sides and edges of the feature. Soils displaced in this manner began notably collecting at the bottom of the feature together with assorted organic detritus. Earthworms began tunneling throughout A- and E-horizons and within two weeks and were well established in the bottom of the feature as well. The first slump in XF 2 walls occurred the first week of April 1998.

Freezing weather in mid-March caused areas of ice to form in the upper half of XF 2 where ground water had perked out of the feature walls. This ice loosened soils, which washed into the feature bottom during ensuing rains. Periodic rains during March inundated the excavations, aiding the influx of soil and organic debris into the feature. Ongoing minor erosion of the walls was noted along the vertical extent of the feature. The frequent rains kept the feature walls soft and moist causing minor slumping and facilitating worm action. Vegetation began to grow around the rims of the feature by the first week of April and, within another two weeks, was growing out of the upper side walls. A larger pebble (6 x 4 cm) fell out of the wall in XF 2 at the end of April, after it had apparently been partially exposed by earthworm activity. A total of seven centimeters of infilling occurred in the first two months.

Faunal activity included the presence of earthworms, insects, and toads. A toad was recorded in XF 2 at the end of April and remained there through observations made on May 21, 1998. It may have been subsisting on earthworms and likely consumed a beetle that had also been entrapped for a time.

A significant amount of infilling of XF 2 occurred over the three-year observation period (Figure 10.44). The original depth of 0.97 m was reduced to 0.59 m as a result of accumulation of soil at the base of the feature.

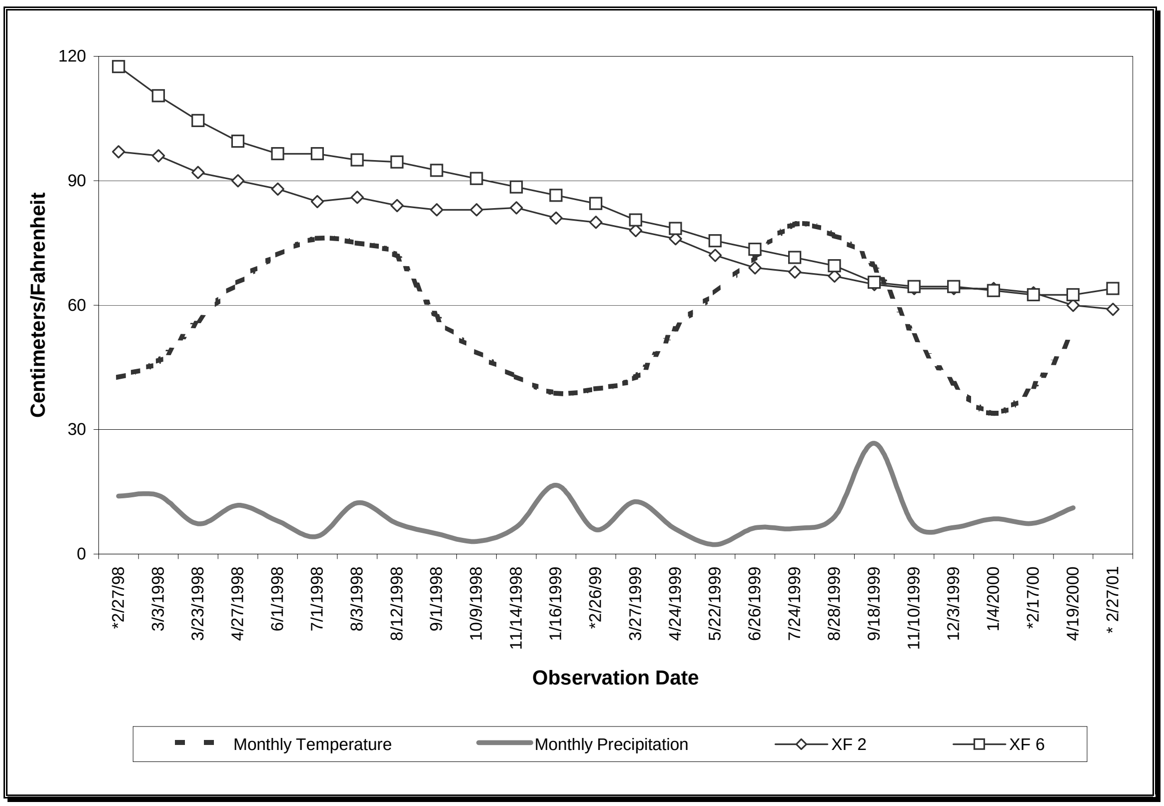

Figure 10.44 Rate of Infilling Compared to Monthly Precipitation and Temperature for XF 2 and XF 6

Comparison of the initial excavation profile and the profile recorded after three years of observation illustrated significant changes in the morphology of XF 2 (Figure 10.45a). The steep walls and conical shape weathered and became more undulated on one side and gradually tapering on the other. The increased slumping in the southern half (northern exposure) may be the result of less direct exposure to the sun allowing moss to form along the rim of the feature. The moss growth stabilized the soil on the rim, whereas the less stable walls of the feature began to undercut causing the undulated morphology. The pointed base was smoothed to a rounded bottom and slumping was evident for the surface adjacent to the orifice. The resultant slumping gave the feature a much wider appearance than the initial excavation.

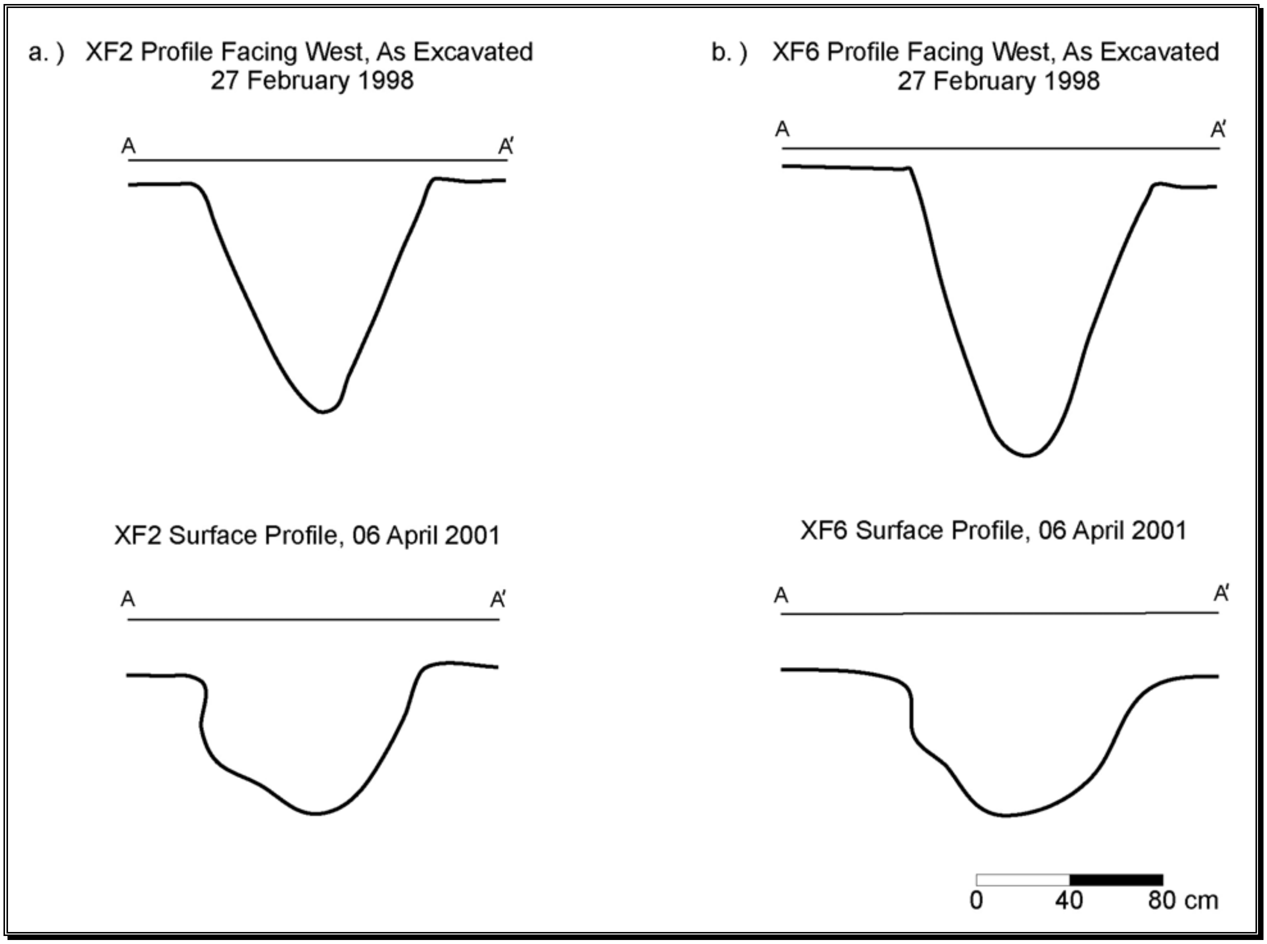

Figure 10.45 Morphological Comparisons for Deep Conical Basins (XF 2 and XF 6) over the Course of the Observation Period

XF 3

XF 3 was a shallow circular, bowl-shaped basin. The original experimental excavation was 0.90 m in diameter by 0.42 m deep. Backdirt was removed from the vicinity of XF 3. Within a week of construction, earthworm activity was apparent throughout the feature. As the season progressed, the rainfall smoothed the edges and walls and an accumulation of soil and debris was noted at the bottom of the feature. However, erosion of the feature walls appeared less pronounced than on deeper sided excavations. Some frost disturbance of the feature walls was noted. By late March 1998, weeds were growing around the rim of XF 3. The location of Feature XF 3 received significant solar exposure, and a notable increase in vegetative growth over the shaded experimental features was noted. Approximately 10 cm of infilling was recorded during the three-year observation period with an original depth of 0.42 m and an ending depth of 0.32 m (Figure 10.46).

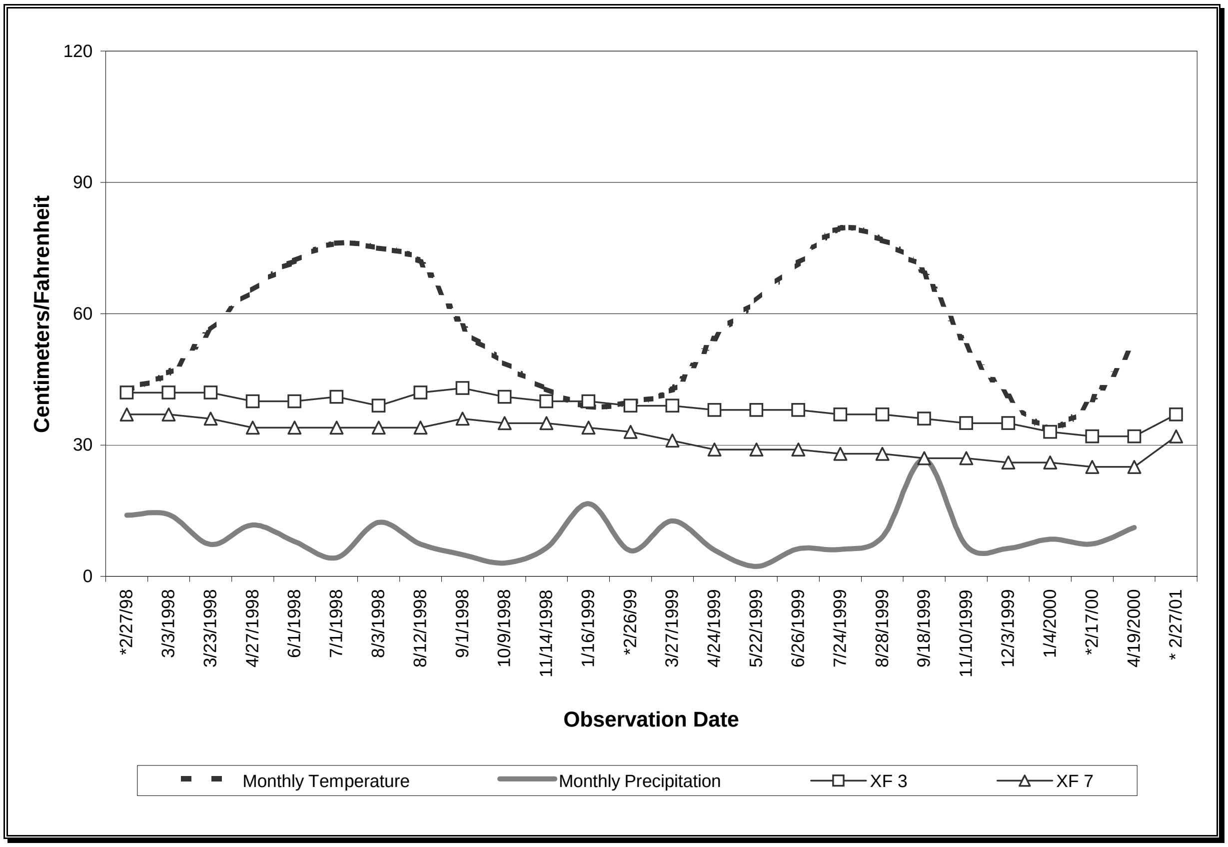

Figure 10.46 Rate of Infilling Compared to Monthly Precipitation and Temperature for XF 3 and XF 7

Comparison of the initial and three-year profiles indicated a degree of slumping for XF 3 (Figure 10.47a). This slumping was most notable at the top of the feature as the surface around the initial opening had caved in and left the sharp cuts less evident. The bottom of the feature became more rounded and lacked the levelness of its initial form. The south half of the feature experienced more weathering and lost a greater degree of its initial morphology. Again, this may be due in part to less exposure to the sun, resulting in moss growth that stabilized the rim of the feature allowing a greater degree of wall slump below the moss.

XF 4

XF 4 was a deep circular feature that was excavated and immediately backfilled. The original excavation measured 1.00 m wide by 1.00 m deep. This feature type was intended for re-excavation and evaluation for microstratigraphic characteristics.

Soils in XF 4 began to subside noticeably within a week of being filled. However, other than a gradual deflation of the fill, no visible changes were observed. Vegetation did not take hold of the surface of XF 4 until the first week in May 1998. This was more than a month later than on the experimental features left open. By the end of summer 1998, XF 4 was completely covered in vegetation. At the end of the study, XF 4 had subsided 11 cm below the ground surface (Figure 10.48). Subsidence was greatest on the edges of the feature as the center subsided only eight centimeters (Figure 10.49a). Re-excavation of the feature has not yet been undertaken.

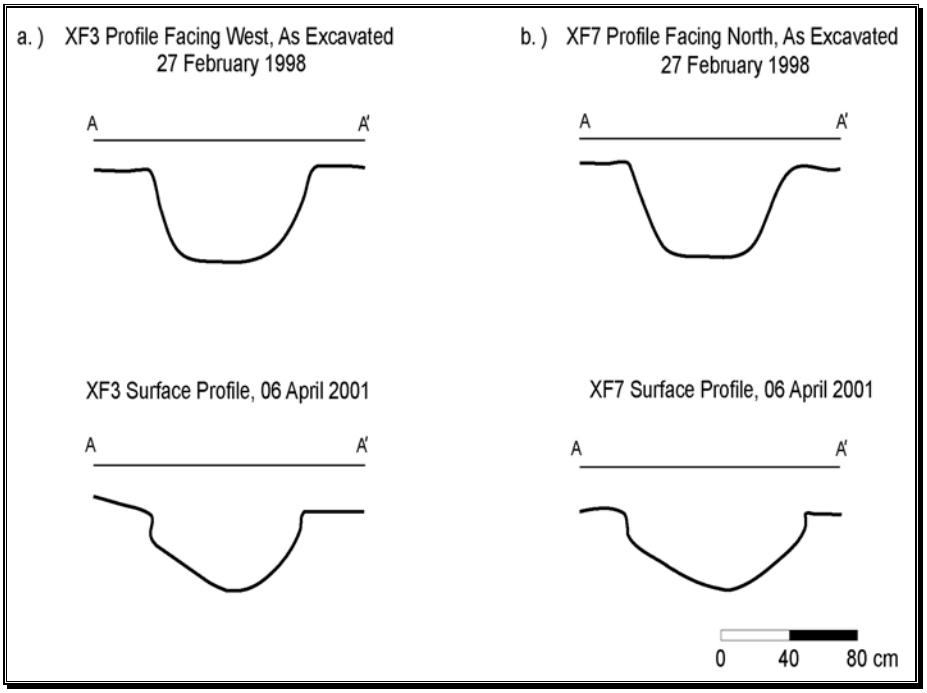

Figure 10.47 Morphological Comparisons for Shallow Bowl-shaped Basins over the Course of the Observation Period

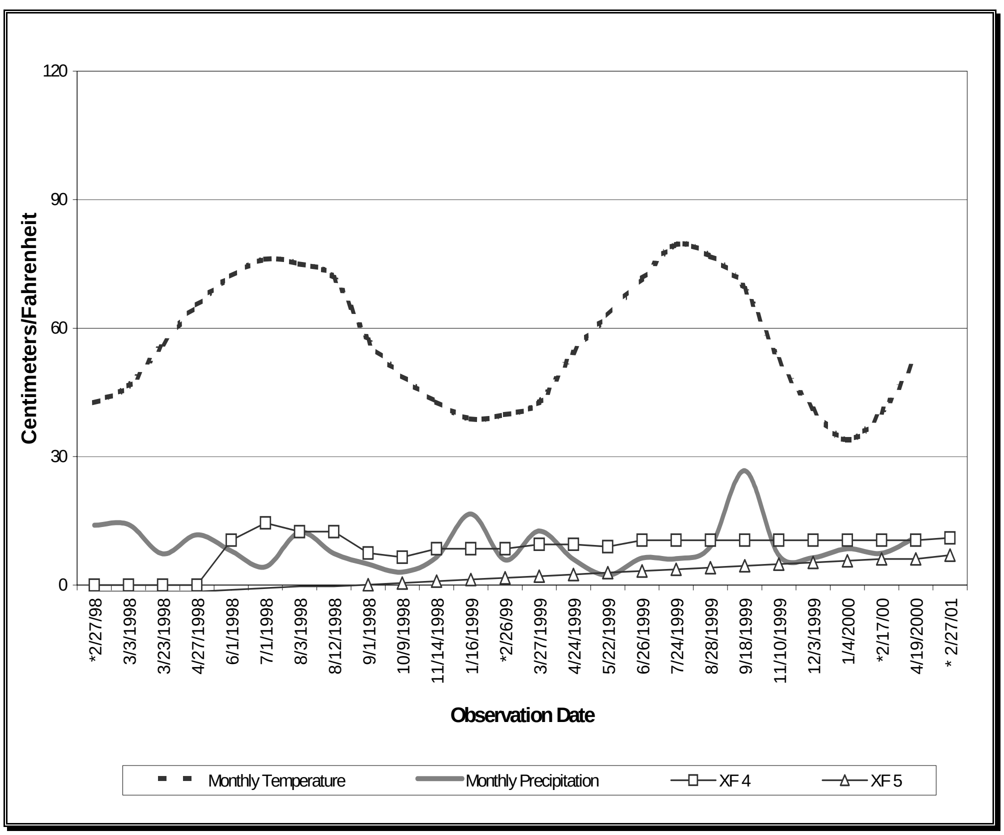

Figure 10.48 Rate of Subsidence Compared to Monthly Precipitation and Temperature for XF 4 and XF 5

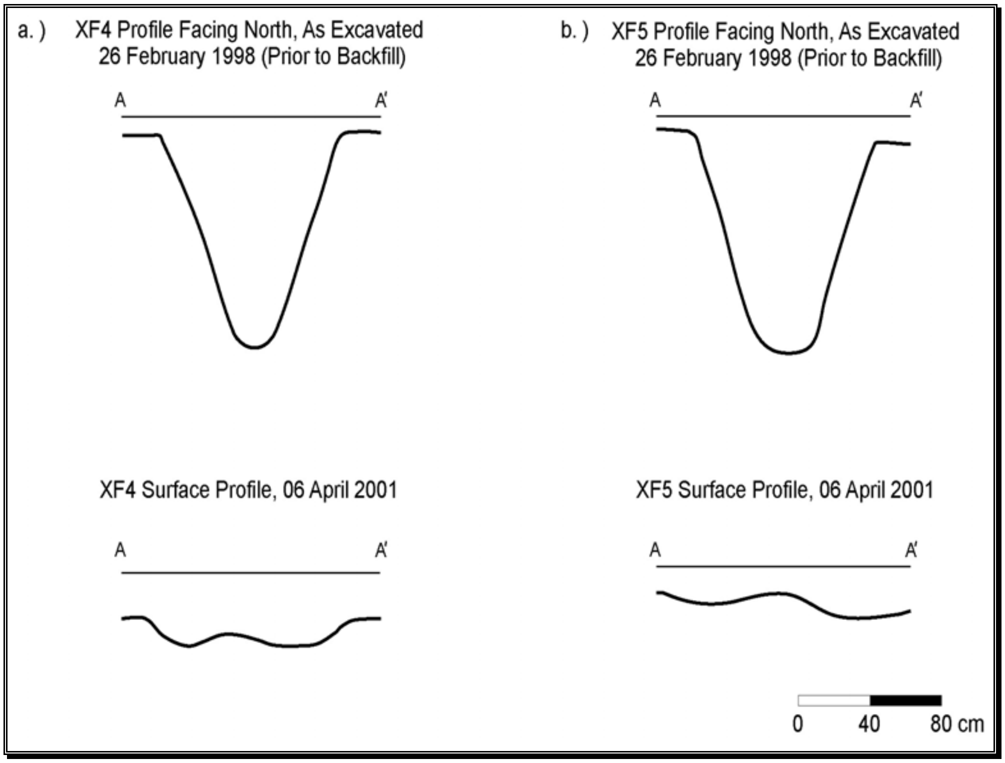

Figure 10.49 "As Excavated" and Surface Profiles of Backfilled Basins

XF 5

XF 5 was a deep circular feature measuring 1.00 m wide by 1.00 m deep. It was excavated through the overlying strata into the subsoil, and then immediately backfilled. Subsidence in XF 5 was noticeable within a week of the excavation and refilling. No other visible disturbances on the surface were observed throughout the study other than a gradual deflation of the fill. Plant growth on the surface of XF 5 was recorded for the first week in May 1998.

By the end of summer 1998, XF 5 was completely covered in vegetation. Observations in the Fall of 1999 noted a ~2.00 m sapling growing near the eastern edge of the feature. This feature type was intended for re-excavation and evaluation for microstratigraphic relationships. At the end of the study, XF 5 had subsided seven centimeters from its original depth (Figure 10.48). A surface profile obtained at the end of the three year observation period revealed a slightly undulated surface with the lesser subsidence occurring within the center of the feature (Figure 10.49b). Re-excavation of XF 5 has not yet been conducted.

XF 6

XF 6 was a shallow circular bowl-shaped basin. The original excavation measured 1.00 m in diameter with a maximum depth of 1.17 m. The excavated backdirt was left in the vicinity of the XF 6 orifice. Excavations cut into sand and gravel deposits of the Columbia Fm. The coarser nature of the soils encountered in XF 6 seemed to have resulted in greater erosion of the side walls than in XF 2, which had a nearly identical morphology.

Marked changes began to occur within a week of construction. Rains began smoothing and rounding the sides and edges of the feature, depositing minor amounts of soil at the base of the feature. Earthworms began tunneling throughout A- and E-horizons and within two weeks, were well established in the bottom of the feature. The first small wall collapse occurred within two weeks of construction.

Freezing weather in mid-March 1998 caused areas of ice to form in the upper half of XF 6, where water had perked out of the sides of the feature. This freezing loosened soils, which washed into the feature bottom during ensuing rains. Periodic rains during March inundated the basin and resulted in the influx of soil and debris into the feature. Side wall erosion was noted along the full vertical extent of the feature. Some size sorting of soil particles was noted as a result of side wall erosion, with gravels left in the side walls as the surrounding sandy matrix gradually eroded into XF 6. Shallow gullies also began to form at the edge of XF 6. The frequent rains kept the feature walls soft and moist, facilitating ongoing worm action and minor soil sloughing. Vegetation began to grow around the rim of XF 6 by the first week of April and, within another two weeks, extended out of the upper side walls. By early May, weeds were present at the bottom of XF 6 and vines from adjoining areas had entered the feature.

During April and May, bioturbation and minor sloughing continued to undercut the lower edges of the side walls, causing further erosion and numerous small wall collapses. Initial depth recordings showed 18 cm of infilling in the first two months. Faunal activity in XF 6 included the presence of a toad recorded in late April 1998. It was not noted at a later date and it is unknown whether it escaped or was eaten by a predator.

The depth recordings of XF 6 showed a change from 1.17 m to 0.64 m over the course of the three-year observation period (Figure 10.44). Comparison of the initial and three-year profile showed significant changes to the morphology of XF 6, as expected from the degree of infilling expressed in the depth changes. The steeply sloping sides of the feature were highly weathered, had become more gradually tapered, and lacked the sharp cuts initially present (Figure 10.45b). The deep conical shape had been transformed to a less regular and shallower form that bore little resemblance to the initial excavated shape. The surface adjacent to the feature opening also experienced slumping as indicated by its uneven appearance and rounded edges. No moss was observed growing on or around this feature.

XF 7

XF 7 was a shallow circular bowl-shaped basin measuring 0.90 m wide by 0.37 m deep. Backdirt was left in the area around XF 7. Within a week of construction, earthworm activity was apparent throughout XF 7, leaving soil mounds and fecal matter that washed into the feature bottom at the first rain. As the season progressed, the rainfall smoothed the edges and walls of XF 7 and an accumulation of debris was noted. Frost action also resulted in the displacement of soil, but apparently to a lesser degree that in the deeper, steep-sided features. Wall slumping and soil sloughing caused by rain events also appeared to be less pronounced.

Feature XF 7 was located in a shaded area. This appeared to initially retard vegetative growth. Later in the growing season, however, XF 7 became fully obscured. Depth recording taken over the course of the three-year observation period showed a change of only five centimeters (Figure 10.46).

The morphology of XF 7 experienced some change over the study period that is evident in a comparison of the initial and third year profiles (Figure 10.47b). The steep sides and flat bottom weathered and become more gradually tapered to a rounded bottom. The surface edges also become more rounded and showed a small degree of slumping. No moss was observed growing in or around XF 7.

XF 8

XF 8 was a large bi-level feature with a narrow, D-shaped basin or “sub-basement” set into a wide, shallow “living floor” area. The living floor area was 3.16 m at its greatest dimension and was excavated to a depth of 0.16 m, while the “sub-basement” was 0.73 m below ground surface. The “living floor” area was thoroughly trampled after excavation in an attempt to simulate a limited daily usage. XF 8 was located at the eastern end of the experimental plot and was well shaded for most of the day. The backdirt was left dispersed in the area adjacent to the excavation.

Worm activity in XF 8 was noted in the sub-basement and on a slight shelf halfway up the eastern wall very shortly after construction of the feature. Drainage of the underlying soils was moderate at best, any substantial rain tended to leave standing water in the deepest portion of the excavation, drowning a large number of earthworms. Repeated rains resulted in the erosion of the feature walls and washed quantities of the backdirt into the excavations. Following the subsidence of the standing water, earthworm activity resumed, and fecal matter and minor soil displacement associated with the tunneling once more became apparent. In mid-March, a series of freezes slowed the earthworm activity and the XF 8 sub-basement was lined with ice spikes, resulting in minor frost heaving. Late March brought additional spring rains, resulting in additional input of soil into XF 8, especially the deeper section. Erosion of the side walls and around the rim was noted. The onset of vegetation growth appeared to anchor some of the looser soil. The vegetation tended to grow more readily on the southern facing portion of the feature, apparently due to increased solar exposure in that area.

By early April 1998, minor soil slumps occurred in the lower portions of XF 8, especially in the sub-basement area. These slumps appeared to be caused in part by soil desiccation brought on by a period of dry weather. The periods of soil drying were short-lived and April brought more rains, resulting in additional erosion of the feature sides. Small pebbles dropped out of the walls and side walls became very uneven and craggy. Earthworms were not the only fauna observed in XF 8. Flies were also observed on the bodies of decaying earthworms in the bottom of XF 8 and were likely laying eggs there.

Maple seed pods were observed in XF 8 in May 1998; by June, five silver maple saplings had rooted. One sapling was located on the living floor near the southwest edge of the sub-basement. The other four saplings were evenly spaced in the sub-basement floor. In July, a sixth maple sapling was recorded on the extreme northern edge of the living floor surface; one of the saplings in the sub-basement had grown about 0.60 m. Throughout July, additional maple saplings were observed growing on the living floor. By September 1998, the saplings in the sub-basement were approximately 0.90 m high. At the end of the observations, the saplings within the sub-basement were over 1.50 m in height and were 1.5 cm in diameter.

Measurements of depth were taken at two different locations for XF 8: in the center of the sub-basement and on the shallow living floor. A change of depth of 0.73 m to 0.52 m was recorded in the deep "sub-basement" area. Measurements of the "living floor" surface of XF 8 recorded an erosion of the original surface from 0.16 m to 0.23 m over the course of the three-year observation period (Figure 10.50).

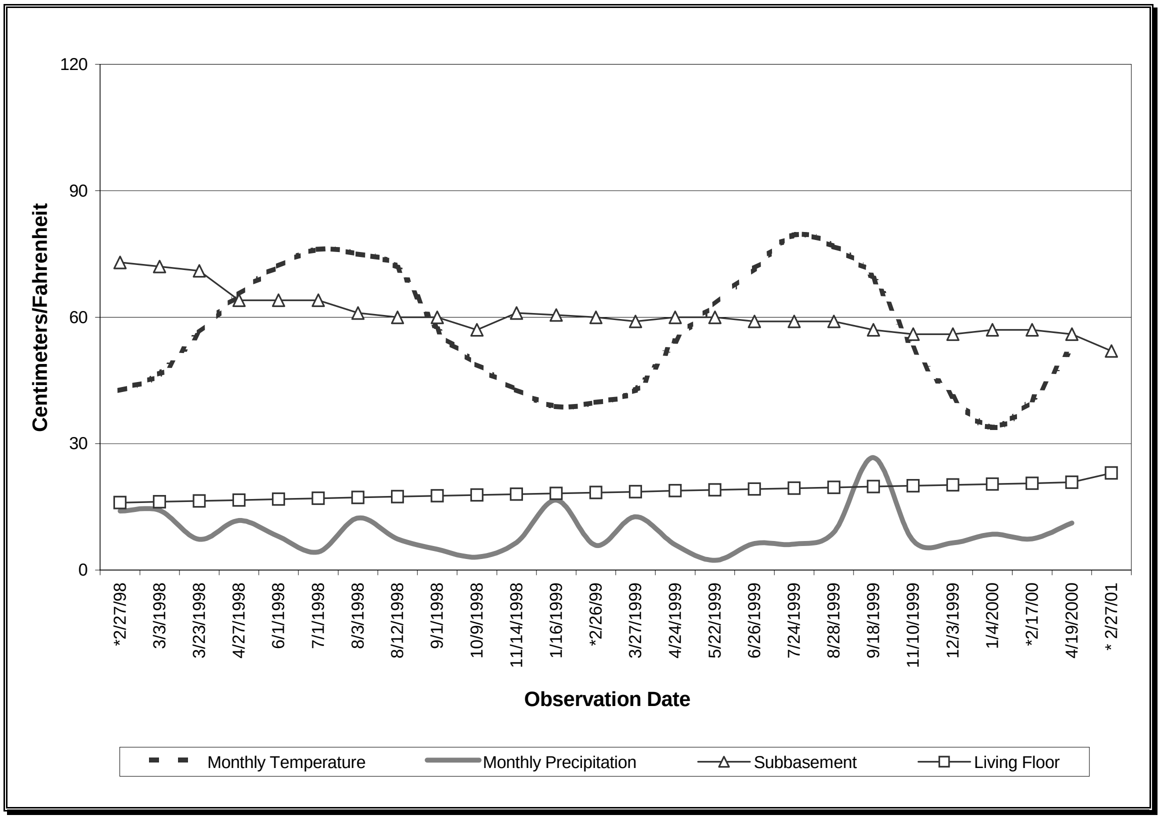

Figure 10.50 Rate of Infilling Compared to Monthly Precipitation and Temperature for XF 8

Examination of the opening and three-year profiles of XF 8 revealed changes in the morphology of the feature (Figure 10.51). The sharp edges of the feature had been filled in first, resulting in a more gradual tapering of the side walls and a more level and rounded bottom. Slumping was apparent in the upper, shallower portion of XF 8 and was now smoother, with the original cuts masked by infilling.

Comparisons and Summary

A variety of natural environmental processes were viewed throughout the study time frame and showed a tempo and mode to various processes (e.g., weather changes, animal interactions, and plant growth). For open experimental features, a collapse of side-walls and a change in general morphology was observed. The backfilled experimental features were subject to animal burrowing and plant growth in their upper horizons, causing movement of sediments. The observational information indicated that open and closed experimental features immediately interact with the natural environment in numerous ways, and that basin infills are the cumulative effect of pre-burial and post-burial processes. Variations in feature depth were recorded through