Appendix B

Geomorphological Evaluation

Geomorphological Investigations at the Proposed St. Annes Church Road and Bridge Renovation and Relocation Project, New Castle County, Delaware

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1.0 INTRODUCTION

1.1 General

This study involved a geological/geomorphological examination of the proposed DelDOT 1-503 St. Annes Church Road and Bridge Renovation and Relocation Project, New Castle County, Delaware. Geoarchaeological investigations were completed under the direction of Dr. Frank J. Vento, PG-001831-G, Clarion University of Pennsylvania, Clarion, Pa. 16214, subconsultant for McCormick-Taylor, Inc.

1.2 Location and Description of Project Area

The St. Annes Church Road and Bridge Renovation and Relocation Project is situated in the town of Middletown, Delaware (Figure 1). The project entails realignment of the existing road to the northwest and construction of a new bridge to the north of the existing span. The principal landforms within the project area include the valley bottom of Deep Creek and a rolling upland surface capped by Pleistocene age sands and gravels of the Columbia Formation. Locally, the Columbia Formation is disconformably underlain by glauconitic sands of the Paleocene Age. Elevations within the project area range from 18.3 m (60 ft) just west of the cemetery along St. Annes Church Road to approximately 3 m (10 ft) above sea level along the thalweg of Deep Creek.

Deep Creek proper, the principal drainage line within the project area, flows due east to its confluence with Silver Creek/Lake. From its artificial impoundment just downstream from its confluence with Deep Creek, Silver Creek continues flowing east to its confluence with Delaware Bay. The gradient along Deep Creek is approximately 1.5 m (5 ft) per mile. The steep entrenched (or incised) character of Deep Creek is resultant from the low (91.4

m/300 ft or more) late Wisconsin age sea level stand present during the Woodfordian Stade. In response to rapid sea level lowering, Deep Creek and Silver Creek responded by deeply incising their channels to keep pace with the drop in sea level. Since the initial phase of deglaciation (circa. 15,000 yrs B.P.), sea level has risen resulting in the drowning of Delaware Bay. Given the downstream control on Deep Creek and Silver Creek by Delaware Bay, these streams also stabilized their channels by approximately 6,000 yrs. B.P. This stabilization or graded condition allowed for a lower gradient, the development of a meandering channel habit, and the initiation of Holocene vertical accretion/aggradation of the valley bottom zone of Deep Creek.

1.3 Purpose of Investigation

The objectives of the geomorphology study was to: 1) identify the various landforms and associated soils present within the project area, 2) discuss sediment supply, sediment provenance (aeolian vs. fluvial) and modes of sediment transport that have operated, and are operating, within the study area, 3) determine the age(s) of the soils present on the valley bottom of Deep Creek, as well as on the flat upland surface bordering St. Anne's road, 4) identify areas of prior disturbance, if present, and 5) determine the depths to which testing should extend to ensure the recovery of any and all potentially significant cultural resources.

1.4 Scope of Investigation

This investigation was performed by Dr. Frank J. Vento, Professor, Department of Geography and Geology, Clarion University of Pennsylvania. The study included a review of both general and specific references of the bedrock geology and quaternary history of the project area. In addition, topographic maps, geologic reports, hydrologic information and aerial photographs were reviewed. Field investigations were initiated on 21 April 2008 and included a pedestrian surface reconnaissance of the study area. In addition to the pedestrian walk-over, a number of deep, 4 inch bucket auger probes were emplaced along the project area corridor (Figure 2). The objective of the auger probes was to examine the full range of soils present on the various landforms identified during the pedestrian reconnaissance. All of the auger probes were excavated into culturally sterile lithostratigraphic units of the Columbia Formation or, in the case of the valley bottom zone, into coarse grained vertical and lateral accretion deposits which have no potential to contain in situ prehistoric cultural resources.

2.0 PERTINENT ENVIRONMENTAL BACKGROUND INFORMATION

2.1 Physiography and Geomorphology

The St. Annes Church Road and Bridge Renovation and Relocation project area is situated in the Embayed Section (Lower Shore of Delaware) of the Atlantic Coastal Plain physiographic province. The Embayed Section extends from north of the Neuse River in North Carolina to a somewhat debatable boundary near Cape Cod, Massachusetts (Thornbury 1965), and is defined by the occurrences of submerged river valleys. From Long Island, south to the James River in Virginia, this embayment reaches inland to the Fall Line, which marks the contact of Coastal Plain sediments with older lithologies of the New England and Piedmont physiographic provinces.

Post-glacial submergence along this reach of the Atlantic Coastal Plain resulted from isostatic adjustments of the crust level due to ice-loading, concomitant with a rise in base level due to ablation of the late Wisconsin ice sheet. The degree of submergence diminishes from north to south as evidenced by a northward decrease in the width of the Coastal Plain and the altitude of its inner edge. North of Cape Cod, the Coastal Plain is completely submerged and has become a portion of the continental shelf (Thornbury 1965:36).

2.2 Drainage and Hydrology

The drainage pattern of the Eastern Shore zone of the Embayed section is clearly dendritic, with numerous external and internal links supplying the main stem of Delaware Bay. The few streams in the region are deeply incised and exhibit valley bottom zones which are often swampy or extensively flood scoured. The extensive flood scouring observed along the valley bottom of Deep Creek is due to historic deforestation of the upland surface which promoted rapid surface runoff, high discharges, and increased sediment yields to stream in the region. In addition, there is a marked asymmetry in stream length within the region, with the east-flowing drainage lines exhibiting a distinctively longer course than those which flow in a westerly direction. This occurrence is due to the fact that the east-flowing streams follow the east/southeast dip of the geologic units in the region. Homoclinal shifting of drainage divides on the Eastern and Western Shores occurs along the down dip direction.

As noted above, Deep Creek flows eastward to its confluence with Silver Creek. The Holocene marine transgression, beginning approximately 11,000 years ago and continuing today at a rate of 2 mm per year, was responsible for the drowning of Delaware Bay and the lower reaches of Silver Creek. Until sea level stabilized around 6000 yrs. B.P., aggradation of the valley bottom of Deep Creek could not have been accomplished.

Flooding within the study area is dependent upon variations in precipitation. The highest discharges along Deep Creek occur during the late winter and early spring when there is a water surplus and lowered rates of evapotranspiration, while lowest flow volumes occur during the late summer and fall in association with decreased effective precipitation. Sea level rise during the Holocene and historic deforestation of the study area has allowed for increased surface runoff, higher sediment yields, and more frequent overbank discharges. These conditions allowed for the emplacement of a variably thick package of middle to late Holocene age, vertical-accretionary and colluvial deposits along the valley bottom and lower valley slopes of the Deep Creek. Due to the effects of historic deforestation, flooding along Deep Creek has removed much of the original middle to late Holocene age vertical accretion deposits. Presently, on the valley bottom zone, long linear erosional swales cut the terrace surface bordering Deep Creek. The terrace surface today consists of elevated erosional outliers, which still contain some of the late to middle Holocene age overbank deposits, but are then bound by deep, erosional swales comprised of coarse grained sands and gravels.

2.3 General Geology

The Coastal Plain in New Castle County is composed wholly of generally unconsolidated sedimentary deposits ranging in age from late Cretaceous to Holocene. The strike of the deposits is generally northeast-southwest with dips of typically less than several degrees to the east-southeast. Within the study area, the surficial deposits consist of more than 20 m (66 ft) of oxidized sands and gravels of the Pleistocene age Columbia Formation (Figure 3). The Columbia Formation is then underlain by a thick package of glauconitic sands ascribable to the Hornerstown Formation of Tertiary (Paleocene/Eocene) Age. Based upon isopach thicknesses for the Columbia Formation, the Tertiary age glauconitic sands occur between 3 m and 4 m (10 ft to 13.1 ft) below the active channel of Deep Creek, and are not exposed in the project area.

2.4 Soils

Two mapped soil units occur within the project area. These include the mixed alluvial land unit (Mv) and the Matapeake series. The mixed alluvial land soil unit occurs along the lower reach of Deep Creek and consists of variably textured alluvium. The source of the alluvial material along the valley bottom of Deep Creek is material washed from the Pleistocene Columbia Formation. Based upon the field study, it is clear that the mixed alluvial soil unit on the valley bottom of Deep Creek is susceptible to flooding and has been frequently inundated by historic flooding.

The Matapeake soil series is classed as prime farmland. This soil is well drained. The slowest permeability within 60 inches is moderately slow. Available water capacity is very high and shrink swell potential is low. This soil is not flooded and is not ponded. The water table is deeper than 1.8 meters (6 feet).

2.6 Paleoenvironmental Reconstruction

2.6.1 Late Pleistocene

The major expansion of the Laurentide ice sheet took place beginning in the Late Wisconsin stage at about 23,000 years B.P. In most of the northeastern United States the ice sheet was in full retreat by approximately 14,500 years B.P. Over the next four thousand years, there were several short-lived, small advances or pulses of the Laurentide ice sheet. While New Castle County, Delaware was never glaciated, full-glacial and then late-periglacial climatic conditions to the north and west would have had a profound impact on eustatic sea-level changes, rates of weathering and mass-wasting, vegetation patterns, and stream regime.

Bloom (1983) has proposed that during the late glacial maximum (18,000 B.P.) sea level was lowered by 120 m +/- 60 m (394 ft +/- 197 ft), exposing large portions of the continental shelves. In response to a lowered base level, streams like Deep Creek and Silver Creek would have rapidly downcut (through temporary base level adjustment) to keep pace with the lower base level of Delaware Bay/River. The steep, entrenched valley profiles in the region indicate a rapid phase of incision with minor lateral channel migration. The sandy parent material, greater effective precipitation, and heightened stream competence/capacity would have allowed for rapid rates of incision. This is clearly evidenced at Deep Creek where the stream has down cut nearly 15 m (50 ft) in response to the late Wisconsin low sea level stand. All of this incision was through unconsolidated sands and gravels of Pleistocene and Tertiary age. Given the absence of any ice within New Castle County, isostatic adjustments relating to ablation of the Laurentide ice sheet would not have affected late Wisconsin or early Holocene rates of incision.

At the peak of glaciation, changes in radiation and insolation caused the jet stream to split into two portions, with strong easterly winds occurring at the southern margin of the ice sheet (COHMAP 1987; Ebright 1992). As noted by Ebright et al. (1988) these late glacial weather patterns would have resulted in a decrease in sea water temperatures, increase in sea-ice areas, and a decrease in seasonality in eastern North America. Brush (1986) places the average land temperatures at 3 to 8 degrees Centigrade lower than present near the end of the glaciation in the Chesapeake Bay area. Other authors have argued (Webb and Bartlein 1988; Knox 1983; Vento, Rollins, Raber et al. 1992) that it was not until 9,000 - 8,000 yrs. B.P. that the continental ice mass no longer affected continental atmospheric circulation (occurrence of meridional flow) and vegetation patterns.

Late glacial forest-vegetation communities consisted of boreal species dominated by jack pine and spruce, with lesser amounts of birch, fir, hemlock, and alder (Brush 1986; Delcourt and Delcourt 1981, Davis 1983; Sirkin et al. 1977). Pleistocene-age peats from eastern Pennsylvania and the Delmarva Peninsula exhibit a diverse spectrum of forest taxa including pine, spruce, birch, alder, willow, oaks, heaths, grasses, and sedges (Sirkin et al. 1977; Crowl and Sevon 1980). Like the flora, Pleistocene fauna was equally diverse including such fauna as mastodon, mammoth, bison, horses, and camel (Guilday et al. 1966; Semken 1983; Eschelman and Grady 1986). The cause for the Late Pleistocene extinctions generally follows one of three models: 1) overkill; 2) environmental change, and 3) combined effects of overkill-environmental change. Specific details regarding Pleistocene extinctions are reviewed by Lundelius and others (1983). It might be argued that the late glacial fauna (11,000 - 10,000 yrs. B.P.) of New Castle County, Delaware was a mosaic of both megafauna and more modern Carolinian species.

2.6.2 Early Holocene (10,000 - 8,000 B.P.)

By the start of the Holocene (circa. 10,000 yrs. B.P.) the Laurentide ice sheet had ablated to a position just south of present day Hudson Bay. The stagnant ice sheet effectively restricted the mixing of warm-moist air masses from the Gulf of Mexico with cold Canadian air. In effect, the flow during the early Holocene was clearly zonal or westerly. Prior to 7,000 yrs. B.P. flood intensity in the mid Atlantic States would have been greatly reduced. Also, during this time, rapid, eustatic sea-level adjustments along the Atlantic coast caused drowning of numerous river valleys. Kutzbach's (1983) notes that the radiation curves for tilt and precession reinforced each other at 10,000 - 9,000 yrs. B.P. resulting in the global average solar radiation for July being 7% greater than today and that precipitation was 7% greater and temperatures 0.7 degrees Celsius warmer.

As relates to the drainage lines within the general study area, the early Holocene would have been a time of rapid alluviation-aggradation. Aggradation would have been caused by a base-level adjustment due to eustatic sea level rise. During this time, gradients were much reduced from the earlier late Wisconsinan as were sediment load and overall discharge. The probable braided reaches of these drainage lines changed their channel habit to one of a meandering form. In the interior part of the mid-Atlantic region, infrequent large floods during the early Holocene would have been promoted by strong zonal/westerly flow and greater rates of potential evapotranspiration.

Within segments of the Delaware and Susquehanna River basins, the major drainage lines experienced several episodes of rapid, vertical accretion followed by several hundred-year periods of relative flood-plain stability (see Figure 3). The multiple, dated occurrence of cumulic, buried A-horizons from the period 9,000 - 8,000 yrs. B.P. indicates a relatively lengthy period of flood plain stability (Vento, Rollins, Raber et al. 1992). During the early Holocene, the spruce and pine forest of the late glacial stage was rather quickly replaced by mixed conifers and northern hardwoods (Delcourt and Delcourt 1981; Davis 1983; Brush 1986). Both Brush (1986) and Davis (1983) note oak as occurring within the general study area by 10,000 yrs. B.P. Pollen cores from the southern Chesapeake Bay region document the rapid expansion of mixed deciduous-conifer forests at 10,000 B.P. (Harrison et al. 1965; Whitehead 1972).

2.6.3 Middle Holocene (7,000 - 5,000 B.P.)

The Middle Holocene along the Middle Atlantic coast is a period during which sea level rise rapidly increased (Kraft 1985). The head of the Chesapeake Bay at this time was in the vicinity of Annapolis (Brush 1986). Continued ablation and retreat of the ice sheet by 7,000 - 6,000 yrs. B.P. allowed for the penetration and mixing of warm-moist, maritime-tropical air masses with cold Canadian/arctic air (Knox 1983). This mixing created the potential for large cyclonic storms and, in turn, large floods. At this time there is a rapid shift from zonal to more meridional circulation. In the Delaware and Susquehanna River drainage basins most medium to small-sized streams clearly lack any intact mid- to early-Holocene alluvium. The occurrence may be due to the effects of large floods spawned from cyclonic storms removing these earlier vertical accretionary deposits. Also during this time, there is a marked shift from the warm-dry conditions of the late Early Holocene (circa. 9,000 B.P.) period to one of alternating cool-wet and warm-moist conditions. These conditions favored incision and minor active lateral channel migration.

According to Kraft (1985), between 8,000 - 4,000 yrs. B.P. sea level rose at a rate of approximately 0.4 cm per century in the Mid-Atlantic. Joyce (1988) proposes that the warm-dry Hypsithermal Interval prevailed between 9,000 - 5,000 B.P. in the Mid-Atlantic. This period fits well with vegetation shifts observed in the Midwestern Prairie Peninsula and Great Plains. These dates are considerably earlier than estimates based upon pollen core data from Hack Pond which restrict the period of warmth and dryness to the Subboreal (ca. 5,100 – 2,800 B.P., cf. Carbone 1976; Custer 1984; Custer and Curry 1982). These later dates also conform well to dated soils located on low terraces (Port Huron) within the upper and central Susquehanna and upper Delaware River Valleys (Figure 3). Vento, Rollins, Vega et al. (2008) would place the period of warmth and dryness between 4,500 – 3,000 yrs. B.P.). These dates are based upon dated, buried A-horizons which consistently bracket a cambic B-horizon which contains Transitional Archaic artifacts (e.g., broad-spear projectile points, steatite). As relates to vegetation, the mixed conifers and northern hardwood forests of the early Holocene were quickly replaced by an oak-hickory-southern pine association that was firmly in place by 5,000 yrs. B.P. in Maryland (Ebright et al. 1992).

2.6.4 Late Holocene (4,500 - Present)

The opening of the late Holocene is marked by an episode of extreme warmth and dryness known as the Sub-Boreal climatic phase. The warm-dry conditions are in marked contrast to the generally wet-moist conditions of the preceding Atlantic climatic phase. During this period (4,500 – 3,000 yrs. B.P.) a persistent mean-westerly atmospheric circulation expanded a mid-continent climatic regime of warmth and aridity (Bryson et al. 1970; Delcourt and Delcourt 1985; Knox 1983; Vento, Rollins, Raber et al. 1992; Vento, Rollins, Vega et al. 2008). In the upper and central Susquehanna River drainage basin, the stratigraphic evidence indicates that in response to these warm-dry conditions, streams entered a phase of active lateral channel migration and along specific reaches, active vertical accretion. These events may relate to a decreased vegetation cover associated with higher sediment yields. The general absence of any buried A-horizons at this time on dated terraces would appear to indicate that floodplains were receiving enough sediment from flooding to preclude their development.

Recent fossil pollen data, from Dan's Bog, Prince George's County, Maryland, indicates an increase in herbaceous taxa in the oak-dominated forests between 5,000 and 1770 B.P. (Leedecker and Koldehoff 1991). Davis (1983) and Winkler (1985) note that annual average temperatures may have been as much as 2 degrees Celsius warmer than at present.

Following the end of the Sub-Boreal climatic phase, streams along the eastern shore would have experienced a rather pronounced episode of warm and moist climatic conditions (3,000 – 1,750 B.P.) of the Sub-Atlantic climatic phase. These warm-moist conditions allowed for relative flood plain stability and in places, the development of a thick, surficial A-horizon. The Sub-Atlantic phase was then followed by a period of cool-moist conditions of the Scandic climatic phase (circa. 1,750 – 1,150 B.P.). Locally, streams would have entered into a phase of active lateral channel migration and incision with more active rates of vertical accretion, which would have precluded A-horizon development. The Scandic phase was then followed by another warm-moist interval termed the Neo-Atlantic climatic phase (1,100 - 700 B.P.). Warm-moist conditions would have again favored relative floodplain stability. Once again, it might be expected that lower lying terraces should contain, along select reaches, buried A-horizons from this period. If present along the lower terraces, these A-horizons should be overlain by variably thick sola which have been emplaced during the cool-wet, Pacific climatic phase (700 B.P. - 300 B.P.) and as a result of increased surface runoff/sediment yields to streams from historic deforestation. According to Brush (1986), sea level continued to rise but at a much slower rate, and Delaware and Chesapeake Bays had essentially attained their present form at approximately 3,000 yrs. B.P. Kraft (1985) estimates sea level rise of the last 2,000 years at 15 cm per century.

The oak-hickory, southern pine forests typical of early Holocene times remained stable until, as noted above, Euro-American settlement. Brush (1986) notes an especially wet period between 4,700 – 3,400 yrs. B.P. and an extremely dry period between 1,000 - 1,200 A.D. This latter dry period is based upon the presence of holly, chestnut, and ericaceous shrubs. These dates and the associated climatic conditions are exactly the reverse of those proposed for the central and upper Susquehanna River valley (Vento, Rollins, Raber et al. 1992). The high quantities of metallic elements found in cores at this time has led Brush (1986) to postulate that this proposed dry period was characterized by intermittent fires. An alternative hypothesis for the occurrence of abundant free carbon and higher levels of metallic elements might be from aboriginal clearing of land for horticultural/agricultural use.

3.0 RESULTS OF INVESTIGATION

Based upon a detailed geomorphic analysis of the study area, and for ease of discussion, the project area can be separated into four distinct areas or zones. These include: 1) upland surface east of the bridge and west of the cemetery, 2) area of corridor which crosses the former Middletown landfill site, 3) upland surface west of the landfill area, and 4) valley bottom zone along Deep Creek.

Eastern Upland Segment:

The eastern upland segment is situated immediately north of St. Annes Church Road and southwest of the St. Annes Cemetery (Figure 4). From this area, the proposed new roadway will then cross the upper reach of Deep Creek. The soils (Matapeake Series) examined along this segment have formed in sands and gravels of the Pleistocene age Columbia Formation. A typical profile consists of a thin (8 cm thick) fill horizon which disconformably overlies a 20 cm thick, dark brown gravelly sand A horizon (Figure 5). The A horizon is then conformably underlain by a gravelly sand (C horizon). The Columbia Formation along the project area corridor attains a nominal thickness of 20 m (66 ft) and is then disconformably underlain by Tertiary age glauconitic sands (Figure 6).

Figure 4. Photo showing a view (at 260°) of the eastern upland section of the project area and auger probe location.

Figure 5. Soils encountered at the eastern upland location consist of a fill horizon overlying sands of the Columbia Formation. Note that no overlying Holocene age aeolian sands cap or mantle the Columbia Formation within the project area.

Phase I testing along the eastern upland segment can be accomplished by standard shovel test probes. The probes should extend at least 20 cm into the C horizon. There is no evidence of any Holocene age wind blown deposits capping the Columbia Formation along the eastern segment of the roadway corridor.

Former Landfill Segment

The former Middletown landfill segment of the proposed roadway corridor lies southwest of an active railway grade. Based upon the recent geologic field study, as well as an examination of the Tetra Tech field report and borings at the landfill site, it is clear that no archaeological investigations are warranted or recommended. (See Tetra Tech 2008 report for images clearly defining the boundary of the landfill area.)

Western Upland Segment

The western upland of the proposed new roadway will lie essentially southwest of the mapped landfill area. The roadway in this area will cross a wooded area (part of which lies in the landfill area), while the remaining part of the roadway will extend to the north of St. Annes Church Road in a large plowed field area (Figure 7). The soils identified throughout this area are of two distinctly different parent materials. The soils along the extreme southwest segment occur in an area where the land surface is gently rising to a well-defined knoll. In this area the soils have formed in sands and gravels of the Pleistocene age Columbia Formation. A typical profile consists of a 20 cm thick gravelly sand Ap horizon which is then underlain by a strongly oxidized reddish brown gravelly sand C horizon (see Figure 6). Given the absence of any Holocene age alluvial, colluvial, or eolian materials capping the Pleistocene sands and gravels in this area, testing can be accomplished by standard shovel test probes. As one proceeds downslope toward the tree line, the soil profile is distinctly different. The soils have formed in Holocene age alluvial deposits emplaced by backflooding along the main stem and tributaries of Deep Creek. These alluvial deposits comprise a rather small area (approximately 20 m/66 ft) along the roadway corridor. A typical profile in this area consists of a 20 cm to 25 cm thick dark brown silt loam Ap horizon which is then underlain by an 80 cm thick moderate subangular blocky brown silt loam Bw horizon. The Bw horizon is then underlain by relict lateral accretion deposits.

Testing might best be accomplished by the excavation of several 1 m by 1 m deep excavation units. Testing should extend to the top of the relict lateral accretion deposits at 1 m (3.3 ft) below ground surface.

Valley Bottom Zone of Deep Creek

During the course of the geologic field investigations only a single T1 terrace could be identified along the south valley bottom zone bordering Deep Creek. On the north bank, both the T1 terrace as well as a low floodplain zone was noted; however, the north bank lies outside the project area (Figure 8). The most distinct feature of the T1 terrace is that it has been extensively flood scoured such that large, deep swales cut the terrace, roughly paralleling the main stem of Deep Creek (Figure 9). These swales are often bound by higher, preserved segments of the T1 terrace (Figure 10). Auger probes in the swales failed to identify any fine grained overbank alluvium. In fact, all of the auger probes emplaced in these swales consistently encountered coarse sands and gravels of recent to late Holocene age. On the higher outliers of the terrace, the soil profiles did contain a finer grained package of overbank alluvium. A typical profile on these higher outliers consisted of a 10 cm thick A horizon which was then underlain by a 20 cm to 40 cm thick brown silt to sandy loam, subangular blocky Bw horizon. The Bw horizon was then underlain by relict coarse grained vertical and lateral accretion deposits of probable late middle Holocene age. Testing on the valley bottom zone of Deep Creek should be restricted to those preserved higher portions of the terrace that still retain some fine grained Holocene age vertical accretion deposits (see Figure 6).

Figure 10. Fine grained overbank alluvium is preserved on these high outliers of the T1 terrace; photo at 335°.

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