The Archaeology of Waterpower: Reconstructing the Historical Landscape of Milling at Middleford Mills, Sussex County Delaware.

By
Brian Crane, Ph.D.
Cultural Resources Department
Parsons Engineering Science
10521 Rosehaven Street
Fairfax, Virginia, 22030
(703) 218-1486
email: Brian.Crane@parsons.com

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The Middleford Mills, in operation from ca. 1764 to 1900, at various times included a forge, sawmill, planing mill, gristmill, and carding mill. Historical research and field survey conducted by Parsons Engineering Science for the Delaware Department of Transportation mapped the various elements of the complex. Data recovery excavations associated with a bridge replacement project exposed timber foundations of waste gates used to control water levels in the millpond. Historical, archaeological, stream flow, and other geographical data were then combined using GIS analysis to reconstruct the hydrology and operating parameters of the mill complex. The paper explores how results show the complex was rebuilt and reconfigured several times over the course of its more than 100-year existence in response to periodic disasters, changes in the market, and changes in the technology of mills and hydrological science.

HISTORY OF MIDDLEFORD MILLS

Archival research concentrating on Sussex County deeds, warrants and surveys, and court records (available at the Delaware State Archives in Dover) produced a series of maps and documents illustrating development of the Middleford Mills area and the Bridge 238 location **[slide]**. The first documented development to the area occurred in the 1760s, when Joseph Vaughan and Company constructed the "Nanticoke Forge" "on the west side of Northwest Fork of the Nanticoke, at the head of the tide water." The same company owned the "Deep Creek Furnace," approximately four miles to the east on Deep Creek. Although the precise location of the original "Nanticoke Forge" is not known, it likely was situated on or near an 18th-century dam constructed across the Nanticoke River, upstream from Bridge 238. An 1807 survey map shows the location of the old dam (Kent County Warrants and Surveys B9#177) **[slide]**.

The forge operated at least until the Revolutionary War, and possibly as late as the 1790s. The Vaughn Company land was partitioned in 1802, and the tract of land including the Bridge 238 property was sold to William Huffington, Jr. and Thomas Townsend in 1805. Huffington constructed a new dam approximately 300 yards below the first dam (Scharf 1888). This dam, which is also shown on the 1807 map, now carries Route 46. William Huffington and his brother James constructed a new forge after 1805, as well as “2 sets of waste gates,” a sawmill and a grist mill. The 1807 map shows the location of the saw mill and the grist mill on the west side of the dam, and a waste gate or mill race on the east side of the dam, where Bridge 238 now stands. The location of the forge is not shown. It is unclear whether the actual race was reused from the original 18th-century dam, or was constructed in 1805 as part of the new dam.

By at least 1826, Huffington’s ca. 1805 forge was no longer standing. The “Nanticoke Forge” had been torn down some time previously, and in a court case from that year none of the people who testified could remember where the old forge was located, although all agreed the ruins were still visible (Sussex County Chancery Court Case Files H81). In 1825, the Middleford Mills complex was rebuilt, but a fire in 1846 caused extensive damage. In 1857, a new grist mill and saw mill were built on the east side of the dam. A survey made in 1860 illustrates the two mills, the town of Middleford, the mill pond, and the waste gates for the pond (Sussex County Orphans Court Vol. AA-28) **[slide]**. By this time, four millraces were operating. The Bridge 238 location is over a race with a feature labeled as “waste gates”. Another map of the Middleford Mills area was made in 1900, when William W. Rawlins sold the property to Robert C. Purvis (Sussex County Deeds 135:85). On this plot, the Bridge 238 location is shown over a race called “Forge Run” and “Forge Race.” This suggests the possibility that the post 1805 forge may have been located in the vicinity of Bridge 238. The current USGS map shows that the mill pond is now completely gone, and evidence for the races exist as parallel channels of the Nanticoke River **[slide?]**.

EXCAVATION OF THE MIDDLEFORD MILLS

In order to excavate surviving features that had been identified underneath the bridge, below waterline, excavations were carried out inside a 36 x 70-foot cofferdam installed in preparation for the bridge construction itself. The stream itself was diverted through a 48-inch diameter metal culvert **[photo slide]**. Archaeological work began with monitoring of excavation of the 1936 bridge fill. No articulated mill-related remains were found in the bridge fill above the high water mark during removal of the existing bridge and supports. With the cofferdam pumped dry, archaeological excavation proceeded. Methods used included mechanical excavation of fill and recent stream deposits, and hand excavation to expose mill-related timbers **[photo slide]**.

The material of greatest archaeological interest lay beneath the bridge fill and recent floodplain deposits, in the form of wooden features that appeared to be connected with 19th-century water control **[slide]**. In general, the features appear to be associated with three parallel bulkheads that extend across the width of the stream channel. While their function could not be absolutely determined, the features appeared to represent low bulkheads or footers for a superstructure over the stream channel. These were most likely the lower sills for waste gates built originally during the early 19th century. Excavation of these gate sills provided the means to measure the width and depth of this opening from the historic millpond.

Hydrology

In order to understand the significance of the waste gates uncovered beneath Bridge 238, it is necessary to understand the hydrology of the system as a whole **[slide]**.

The mills' hydraulic components (the dam, the pond, the wheels, and the waste gates) were interdependent. The power available to the mills was a function of the headloss (the drop in elevation from the top of the pond to the tailrace). The height of the pond obviously depended on the height of the dam, but how close to the top of the dam the pond elevation could be kept depended on the discharge capacity of the mills and waste gates. The quantity of water flowing into the pond varied with rainfall. In periods of heavy rain, the volume of water flowing into the pond could exceed the total discharge capacity of the mills and gates. If this happened, the level of the pond would rise until either the flow of water into the pond decreased, or the pond had overflowed the dam. Since the latter could have catastrophic consequences, it was important to ensure that either there was enough capacity in the mills and waste gates to discharge excess water, or the level of the pond was kept low enough to ensure there was enough extra capacity in the pond to contain a flood. The greater the capacity of the mills and waste gates, the higher the level of the millpond could be maintained without risking a flood. If the capacity of the pond was low, and the water supply from the river unreliable during dry months, there might not be sufficient water to keep the mills running at capacity the way the mill owners wanted.

[slide] To understand the relationship between the mill complex and the hydrology of the area, it was necessary to reconstruct the quantity of water flowing into the pond, the elevation of the pond surface, the volume of water in the pond, and the discharge capacity of the mills and waste gates. Based on the elevation of likely 18th-century mill features, the original dam was probably not much higher than 5 feet amsl, and was approximately 600 feet long. The resulting pond would have covered 159 acres and held 67 million gallons of water.

Based on historical documents and the USGS 7.5 minute topographic map, the height of the 19th-century mill dam appears to have been more than 10 feet amsl **[slide]**. This dam was approximately 1,200 feet long. The industrial census for 1880 describes the fall in feet for the Grist and Carding mills as 6 feet, and 7 feet for the Saw and Planing mills. The water below the dam would have ranged in elevation from 2.52 feet amsl at high tide, to -0.48 feet amsl at low tide, with the normal water level being 1.02 ft amsl (DelDot 1998). Since the average elevation of the stream below the mills is approximately 1 foot, this means the top of the pond was 7 to 8 feet above sea level. Using ArcView GIS software, a mill pond was reconstructed following an 8 foot contour line upstream from the dam. The shape of a pond at 8 to 10 feet amsl agrees well with 19th-century maps depicting the pond. This millpond covered approximately 215 acres, and would have held approximately 388 million gallons of water. Thus, moving the dam downstream, lengthening it, and raising it by 5 to 6 feet produced a pond with nearly 6 times as much water as the earlier pond. Although the 1807 dam would have been more expensive to build and maintain, the higher dam would have allowed a higher head, and thus more power for the wheels. The larger pond would have allowed the mills the run longer during dry months.

The rate of water flowing into the historic mill pond can be estimated using daily mean discharge data collected by the US Geological Survey from a gauging station (Station number: 01487000) located upstream from the mill on the Nanticoke River Near

Bridgeville, De **[slide]**. Daily data are available for this station from April 1, 1943 through March 12, 1984. Data are not available for what would have been the other tributaries of the pond (Hurley Drain, Gravelly Branch above Fisher's Mill Bridge, Ake Ditch and Turkey Branch). To estimate the quantity of water actually flowing to the mills, the flow rate at the gauging station was multiplied by the ratio of the size of the total mill watershed to the portion of that watershed measured by the gauging station.

During the period for which there is data, the average daily flow was 149 cubic feet per second, with a low of 33 c.f./sec, and a high of 3316 c.f./sec. (on Feb. 26, 1979). September and October averaged the least amount of flow with approximately 76 c.f./sec. March averaged the most flow at 264 c.f./sec.

The water consumption of the late 19th-century mills can be estimated from the power produced, diameter of the wheels, and height of head given in the 1880 Industrial Census. It describes the gristmill as having 2 wheels with 6 feet of head, one of 36 inches in diameter with 25 hp, and another of 30 inches in diameter with 15 hp. It also lists a sawmill with one wheel of 48 inches in diameter, 7 feet of head, and 18 hp. These wheels were likely turbines; using the formula, flow (gpm) = Power*3956/headloss, the total consumption of the mills was approximately 150 cfs, assuming 70% efficiency in the turbines.

A computer simulation was then created which estimates the level of water in the 19th-century mill pond from the historical stream flow data, and adjusts the volume of water flowing through the waste gates to keep the estimated level of the pond between 6 and 8 feet amsl. The simulation was designed to shut off water to the mills if the water in the pond dropped below 7.5 feet amsl. This simulation showed that there was sufficient water to power the mills 98% of the time, assuming the mills did not run more than 12 hour per day. In fact, according to the Industrial Census, only the grist mill was in operation 12 months of the year, the saw mill was in operation 10 months of the year, the planing mill 6 months, and the carding mill only 3 months. The stream flow data and computer simulation suggest that there was more than enough water to supply the power needs for this level of production. In fact, there was considerable unused water capacity.

The 18th-century pond may not have worked as well. If we assume a pond elevation of 5 feet, a dam that is 6.5 feet high, 4 feet of headloss, and 3 mills producing 20 horsepower at 60% efficiency, the mills could have operated as much as 88% of the time. However, unless the dam could discharge well over twice the average streamflow, the complex may have been prone to flooding.

Conclusions

The data suggest several reasons why the early dam was relocated after 1805. Moving the dam downstream, and making the dam higher created a pond with a higher head loss, greater capacity, and a longer dam that may have had a higher discharge capacity. The Middleford Mills were rebuilt at a time when mill engineers were gaining an improved understanding of mill hydraulics. The greater power potential of a higher dam may have been made attractive by the innovations developed by Oliver Evans. Evans' design placed milling operations on multiple floors and was more efficient than previous designs, but required more power.

However, the mill redesign happened before the science of hydrology had advanced to the point where millers could accurately predict seasonal variation in stream flow. The field of hydrology was developing in the early 19th century, but would not mature until after steam had largely replaced water as the principal source of industrial power. The 18th- and 19th-century Middleford Mills seemed to have had adequate water for their operations, although the later dam improved this. Other early 19th-century mill sites suffered from inadequate water supply. Some mill centers in New England were designed for year-round water flows much greater than was available. The Collins works in Collinsville, CT had enough water to run at full capacity for 164 days a year (1,000 horsepower, and 674 cfs); while the Springfield Armory Water Shops probably only had enough water to run 164 days (240 cfs) and the Whitney Armory may only have had enough water to operate 100 days out of the year (Gordon 1985).

That the 19th-century mills did not use all of the available capacity suggests that the enterprise was limited by market forces, rather than available power. By the late 19th century, large, centralized roller mills had come to dominate the milling industry, and may have ultimately doomed the mills as Middleford.

Flood control at Middleford Mills may have been more of a problem than water supply. The 18th-century complex may not have had enough storage capacity in the pond, or discharge capacity through the dam to adequately control storm water. The simulation suggests that the post 1807 complex likely fared better in this, although the ability of the 19th-century waste gates to discharge sufficient water to avoid flooding during high water is still undemonstrated. Excavation of the stream channel showed evidence of gouging from a flood during the 1930s that washed out the bridge. The gate foundations contained circular saw marks, suggesting that the original timbers had been replaced, and other features showed evidence of at least occasional repairs. The computer simulation suggests that if the 2 waste gates together were able to discharge 130 cfs (the average daily flow is 149 cfs), then the pond would not have risen above the dam given conditions similar to the historical streamflow data. However, the dimensions of the gate underneath Bridge 238 suggest a discharge capacity at that gate of only 24 cfs. Whether or not the middle gates could have accommodated more than 100 cfs will not be clear without excavating the foundations of the gates there. It is also possible that there were additional water outlets in the dam where the mills were located. Good integrity of the gate features underneath the middle gates would allow for a more complete reconstruction of the operating parameters of the Middleford Mills.

REFERENCES

Gordon, Robert B.
1985 Hydrological Science and the Development of Waterpower for Manufacturing. *Technology and Culture* 26(2):204-235.

Howell, Charles, and Allan Keller
1977 *The Mill at Philipsburg Manor Upper Mills and a Brief History of Milling.* New York: Sleepy Hollow Restorations.

Kent County Warrants and Surveys
1807 Survey B9, #177. On file at the Delaware State Archives, Dover, Delaware.

Knepper, Dennis
1992 Test Excavations at Lanes Mill (44FX46) Fairfax County, Virginia. *Quarterly Bulletin of the Archaeological Society of Virginia.* 47(4):145-161.

Morin, Edward
1991 Why Dig Another Mill Site? Archaeological Investigations of the East Creek Mill. *North American Archaeologist* 12(2):93-108.

Scharf, J. Thomas
1888 *History of Delaware: 1609-1888*. Philadelphia: L.J. Richards and Co.

Sussex County Chancery Court Records
1826 Case H81. On file at the Delaware State Archives, Dover, Delaware.

Sussex County Deeds
1900 Book 135, page 85. On file at the Sussex County Courthouse, Georgetown, Sussex County, Delaware.

Sussex County Orphans Court Records
1859-62 Volume AA-28. On file at the Delaware State Archives, Dover, Delaware.