Evaluating Archaeological Mill Districts: Using GIS to Identify Key Measurements for Assessing Integrity

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Parsons Engineering Science used GIS technology and historical stream flow data to reconstruct seasonal variations in water supply at the Middleford Mills, Middleford, DE for the Delaware Department of Transportation. Using principals of hydraulics, key measurements for determining how well the mill complex avoided floods in springtime and harnessed sufficient water in dry times were identified. These include the height of the dam, the height and width of waste gates, and the diameter and type of water wheels. Learning how well a mill system harnessed available water resources sheds light on the economic success of the complex, and possibly how the 19th-century mill owners and designers reacted to the evolving science of hydrology. The conclusion is reached that if all or most of the features identified above survive with enough integrity to be measured, then the mill district may be considered to have sufficient integrity to merit National Register eligibility.

INTRODUCTION: STATEMENT OF THE PROBLEM

Just what can be learned from excavating a mill site is a common problem in archaeology. Review of some of the literature on mill sites, and discussion with those who have excavated mills, has sometimes shown a certain disappointment in what was actually learned about the site through excavation as compared with historical research. For example, upon completion of data recovery excavation at the East Creek Mill site in New Jersey, project archaeologists felt that excavation had not been as successful in addressing the research design focusing on milling technology as had documentary research (Morin 1991).

This is a matter of particular concern for DOTs because mills are common elements of the American landscape and are often associated with bridges. As DOTs face a growing number of bridge replacement projects across the country, the fact that many of these bridges may cross mill races, or are located along mill dams, the issues surrounding the evaluation of these resources will become more prevalent.

There are several reasons for the limits on the ability of mill sites to address questions concerning milling technology. The use of waterpower was a fairly conservative technology, and apart from the introduction of turbines in the 19th-century, the technology of mill dams, races, and wheels may not have changed very much over time. Changes in the internal workings of mills are very difficult to get at through archaeology because the machinery from abandoned mills tends to be salvaged rather than left in place. This suggests that either mills as resources don't have as much potential as perhaps was thought, or we may wish to reconsider the kinds of questions we bring to mills.

One research topic that archaeological mill sites have the potential to address is how well mill designers chose sites that would provide an adequate water supply to provide the power necessary for their operations. Recent historical research has shown that, at least among New England millers, this was a major problem, and that partly owing to a poor state of knowledge concerning hydrology, many mills suffered from inadequate water supply for their designs. This paper will approach this problem by exploring how historical research, archaeological excavation, and GIS analysis can combine to reconstruct the operating parameters of a mill complex.

BRIDGE 238 OVER GRAVELLY BRANCH

During July 1999, Parsons Engineering Science evaluated mill-related remains encountered during an archaeological inventory survey for replacement of Bridge 238 in Sussex County Delaware for the Delaware Department of Transportation. Bridge 238 carries Route 46 over the Gravelly Branch of the Nanticoke River near Seaford, Delaware (Figure 1). Initial study found that this branch of the river is an 18th- or 19th-century millrace, and that Route 46 runs along the top of a milldam constructed between 1805 and 1807. Initial fieldwork identified mill-related features spread over a wide area, and a line of wooden posts that cross the southern end of the race above the surface of the water at low tide (Figure 2). Further examination of the floor of the race under the bridge, and along the embankment identified further wood features**.** Interview with a local resident and archaeologist familiar with archaeological features in the area showed that numerous mill and furnace related features were known, including mill machinery, slag piles, borrow pits, and deposits of iron ore. Work then proceeded to use documentary sources to flesh out the history and cultural context of the mill complex, information necessary to deciding on an appropriate field strategy for evaluating the National Register eligibility of the mill site.

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. 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).

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 an 1807 map, now carries Route 46 (Figure 3). 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 gristmill and sawmill were built on the east side of the dam. A survey made in 1860 illustrates the two mills, the town of Middleford, the millpond, and the waste gates for the pond (Figure 4, Sussex County Orphans Court Vol. AA-28). 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.

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. 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.

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. 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 (Figure 5).

RECONSTRUCTING MILL HYDROLOGY

In order to evaluate the significance of the waste gates uncovered beneath Bridge 238, it is necessary to understand the hydrology of the system as a whole. 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 was dependent 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 slowed, 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 pond 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.

To understand 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 18th-century mill features, the original dam was probably between 5 and 10 feet above mean sea level (amsl). 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 milldam appears to have been more than 10 feet amsl. The industrial census for 1880 describes the fall in feet for the mills as 6 feet or 7 feet. 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 millpond 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 (Figures 6 and 7). This millpond covered approximately 215 acres, and would have held approximately 388 million gallons of water. The water below the dam would have ranged in elevation from 2.52 feet amsl at high tide, to -.48 feet amsl at low tide, with the normal water level being 1.02 ft amsl (DelDot 1998). Thus, moving the dam downstream, lengthening it, and raising it by 3 to 5 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 (Figure 8). 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 (cfs), with a low of 33 cfs, and a high of 3316 cfs. (on Feb. 26, 1979). September and October averaged the least amount of flow with approximately 76 cfs. March averaged the most flow at 264 cfs.

The water consumption of the 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 = Power*3956/headloss (gallons/minute), the total consumption of the mills was approximately 150 cfs, assuming 70% efficiency in the turbines.

A computer simulation was 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 shuts off water to the mills if the water in the pond drops 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 hours 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 show that there was more than enough water to supply the power needs for this level of production.

The ability of the waste gates to discharge sufficient water to avoid flooding during high water is undemonstrated. 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 the stream flow data between 1943 and 1984. However, the dimensions of the gate features 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.

CONCLUSIONS

The results of the simulation show that given detailed historical documentation of a mill system, and archaeological preservation of certain of a mill district's hydrological features, it is possible to reconstruct the operating parameters of the mill complex. Particularly valuable historical data necessary for this reconstruction includes:

1. Feet of fall;
2. Historical stream flow data;
3. Number of mills employed, and their horsepower;
4. Size and type of wheels used.

Archaeological dimensions that need to survive include:

1. Height of the dam (especially in areas like southern Delaware where mills were sited on the dams);
2. Width and depth of all waste gates;
3. Type of gates employed;
4. Dimensions of head and tailraces.

If all or most of these data can be collected, then it should be possible to reconstruct what the optimum power needs of the mill were, and how those compared to seasonal water supply. How well a mill adapted to the available water supply would provide information about how much the mill designers knew about the local hydrology (or how lucky they were) and what kinds of constraints there might have been on their business success. With these data available, the case can be made that the water control features within the mill complex retain sufficient integrity to provide important information related to economic history and the history of milling. If the complex lacks all, or most of these data, then there may be little that can be learned about the hydrological operation of the mill, and the water control devices associated with it are less likely to be eligible for the National Register.

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