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The construction of the Potomac aqueduct (1833–1841): Pier construction in deep water conditions

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Last year, in Georgetown, I came across a book published in 1873 by the U.S. Corps of Engineers and entitled, *Report on the Construction of the Piers of the Aqueduct of the Alexandria Canal across The Potomac River at Georgetown* . . . (Turnbull 1873). I was aware of the structure, a masonry pier structure that carried the wooden superstructure of the Alexandria Canal across the Potomac River, just above Key Bridge, at Georgetown. But the date of the book, 1873, was all wrong. The aqueduct had been constructed some thirty-five years earlier. Why would the Corps of Engineers publish a report of the construction of this aqueduct a third of a century after the fact?

In an introductory page, Brigadier-General and Chief of Engineers A. A. Humphreys answered this question; the report was very helpful for engineers facing deepwater pier construction:

> The reports of the progress of the construction of the piers of the aqueduct of the Alexandria Canal . . . were printed by Congress in 1838 and 1841, with accompanying drawings. They have been called for on several occasions by persons engaged in similar undertakings . . . They are of special interest to the engineer on account of the unusual depth of foundation and the difficulties encountered in establishing them. (Turnbull 1877, 3).

The pier construction of the Potomac Aqueduct of the Alexandria Canal had a unique role in the history of American construction. Captain, later Major, William Turnbull, in charge of building the Potomac Aqueduct, was well aware of the uniqueness of this construction project:

> Experience in founding upon rock, at so great a depth, is very limited in this country, there being but one example, viz. the bridge over the Schuylkill at Philadelphia . . . (Turnbull 1838, 7).

Probably Turnbull was referring to the Market Street Bridge in the above quote where building the bridge's piers posed a greater challenge than building the superstructure (Nelson 1990, 43). Up until 1833, American engineers could pretty much ignore the problem of cofferdams and pier construction through the use of large span structures, such as the Colossus of Philadelphia (Nelson 1990) or through the use of suspension bridges. The coming of the railroad changed that. Wider distances would have to be spanned and greater loads carried. On July 4, 1828, the Baltimore and Ohio Railroad, America's first long distance railroad, began construction. By 1833 it was clearly apparent that numerous railroad bridges across deep crossings would have to be constructed so as to drive railroads into the interior of the American continent. But how?

Turnbull was aware of the difficulty he faced in building this aqueduct:

> No descriptive memoir or drawings of this work (i.e. the Market Street Bridge) ever having been published, nor of the London bridges, (the deepest foundation perhaps in Europe,) the engineers, therefore, had to proceed with the

greatest caution . . . The cofferdams for the construction of bridges of Neuilly and Orleans, designed by the distinguished Peronnet, were selected as models . . . (Turnbull 1838, 8).

There was English language treatises on cofferdam and pier construction, such as Charles Labelye's account of Westminster Bridge (Labelye 1751) or George Semple's *Treatise* (Semple 1776), but these were not available to Turnbull.

Siting the Potomac Aqueduct of the Alexandria Canal, 1830–1832

By 1828, the Chesapeake and Ohio Canal had initiated construction and its drive to the west. The Chesapeake and Ohio Canal was to be constructed on the Maryland side of the river thus bringing cargoes, primarily grain, into the port city of Georgetown. Alexandria, on the other shore of the Potomac River, would lose out to its commercial rival, Georgetown. To forestall this, the leading citizens of Alexandria developed a plan to build a canal from just north of Georgetown, across the Potomac River and down to Alexandria. See Figure 1. In 1830 the Alexandria Canal Company was formed. Congress appropriated $400,000 toward its construction. (Hahn and Kemp 1992, 19). The Chesapeake and Ohio Canal Company agreed to build the northern abutment for the needed aqueduct. In 1830, chief engineer of the Chesapeake and Ohio Canal, Benjamin Wright, was directed to supervise the survey of a route of the Alexandria

Figure 1
Site of the Potomac Aqueduct crossing. Looking south down the Potomac River. Georgetown is located at the bottom left of this of this early nineteenth century illustration. The new federal city of Washington is located to the middle left. The Potomac Aqueduct would be constructed immediately upstream of Analostan Island, shown here in the middle of the Potomac River. The Virginia shore can be seen, mostly concealed behind the trees, at the extreme right of the image. Georgetown's commercial rival, Alexandria, is seven miles further downriver (south). Drawing by G. Beck, 1801. Library of Congress

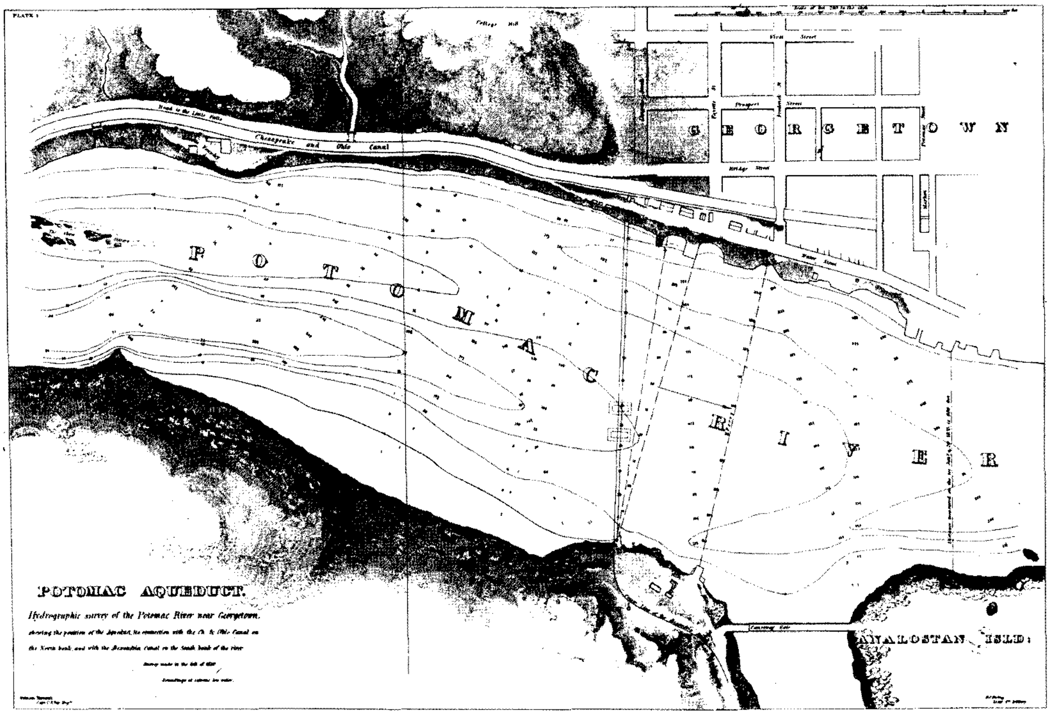

Figure 2
Site plan of Potomac Aqueduct crossing. Site plan of the Potomac Aqueduct. Georgetown and the Chesapeake and Ohio Canal are located in the upper portion of the drawing, Virginia in the lower. The solid, almost vertical line, at right-center of this drawing is the oblique crossing selected by Benjamin Wright and Nathan Roberts. The dotted lines to the right of this solid line indicate the alternate locations selected by Captain William Turnbull. The aqueduct was constructed at the original site. The numbers in the Potomac River indicate river depths. Drawing by Captain William Turnbull and Lieutenant M. C., Ewing. «Hydrographic Map of the Potomac River near Georgetown... Survey made in the fall of 1832.» (Turnbull 1838, Plate 1)

Canal and to take soundings across the Potomac where the aqueduct was to be built (Chesapeake and Ohio Canal Company 1830, entry 182).

Figure 2 shows the site that in 1829 Benjamin Wright and Nathan Roberts selected for the aqueduct. The route is depicted by a solid line from the Georgetown (upper, or northern), shore of the Potomac to the Virginia (lower, or southern) shore of the Potomac. In his official report, Turnbull would criticize Wright for selecting an oblique siting for the aqueduct. Such an oblique siting increased the length of the aqueduct and complicated construction. Turnbull and Alexandria Canal Company engineer W. M. C. Fairfax proposed several alternatives (depicted by dotted lines in Figure 2) which would be of shorter total distance and also bring the aqueduct at right angles with the river flow. These alternative sites were not accepted and the aqueduct was to be constructed on the original site chosen by Wright and Roberts (Turnbull 1838, 3). The total length of the aqueduct on this site would be approximately 1600 feet (487.7 m.).

Turnbull and Fairfax were also critical of Wright's and Robert's attempts to survey the depth of mud in the Potomac River until bedrock could be reached. Wright and Roberts had initiated their survey of underwater conditions by using a 50 foot (15.2 m.) long iron rod for probing the depth of the mud above bedrock. Unfortunately, the iron rod was almost immediately lost (Turnbull 1838, 2). The loss of the iron rod led Wright and Roberts to guess the depth of bedrock under high-water mark at fifteen five feet (4.6 m.) —actually Turnbull and Fairfax later found that bedrock was reached, on average, 28 feet (8.5 m.) below ordinary high-water mark (Turnbull 1838, 4). This meant that the necessary coffer dams would have to be that much more substantial and expensive than originally planned.

Subsurface Investigations for the Potomac Aqueduct —1832

Turnbull probed these subsurface conditions through borings rather than through the use of iron rod probes. He had a square box constructed. The box had interior dimensions of eight by eight inches (20.3 × 20.3 cm). It was constructed of three inch (7.6 cm) thick heart pine blank banded by flat iron bars and 36 feet (11 m.) long. The end of the box that was to be driven into the mud and gravel was shod with steel tipped flat iron shoes, to prevent the driving edge from being damaged by stones. This box was then driven into the bed of the river from a pile driver mounted on a scow, built for that purpose. It was driven as far into the river bed as could be done without damaging the wooden box. This wooden box was then emptied by means of an auger. Turnbull could thus measure the depth of bedrock at each location, as well as the mud and gravel above that bedrock. The wooden box would then be withdrawn and pile driven into the bed of the river at another location (Turnbull 1838, 3). Through this means, Turnbull was able to draw the profile of the river bed.

Design of the Potomac Aqueduct —1832

Once the profile of the riverbed had been ascertained, the engineers could begin designing the structure of the aqueduct. Initially they designed a masonry aqueduct of twelve arches supported by eleven piers and two abutments. The masonry arches were to be of 100 foot span (30.5 m.) and twenty-five foot rise (7.6 m.). The piers were to be of two types: abutment piers, every third pier (three total), of twenty-one feet (6.4 m.) thickness at the springing of the arch; and support piers (eight total), of twelve feet (3.6 m.) (Turnbull 1838, 4). This original plan is shown in Figure 3.

The original plan for the Potomac Aqueduct was modified in several substantial ways by the Board of Directors of the Alexandria Canal Company. First, it was decided that the superstructure, the masonry arches, would not be constructed at this time. The Alexandria Canal Company was tight on money and wanted to have the ability to substitute a wood framed superstructure for the proposed masonry arch superstructure. Second, a 350 foot (106.7 m.) causeway replaced the three arches on the Virginia side of the aqueduct. This change made other changes necessary in the original design. The distance between piers for the masonry arches was increased from 100 feet (30.5 m.) to 105 feet (32 m.). The abutment piers were decreased from three to two and the support piers decreased from eight to six. The thicknesses of the piers remained the same.

Beginning of Construction on the Potomac Aqueduct —1833

By January, 1833, the Alexandria Canal Company began to make plans for the onset of the 1833 construction season, beginning March 1st. On January 29, 1833 the Company advertised for the construction of the aqueduct. Several offers were received, varying from $99,093 to $247,909. One proposal was received from Doctor John Martineau and Stewart. Martineau had a considerable degree of engineering authority, having served as a Director of the Chesapeake and Ohio Canal —an engineering position second only to the chief engineer, Benjamin Wright.

The First Attempt —Circular Cofferdams —1833

Martineau proposed an innovative means of building the piers, through circular coffer dams. These circular coffer dams would be eighty feet (24.4 m.) in diameter. They would be constructed of two circular rims, one resting on top of each other. These rims were of wooden construction, built from 12 × 14 inch (30.5 × 35.6 cm) mounted vertically in ten foot (3 m.)

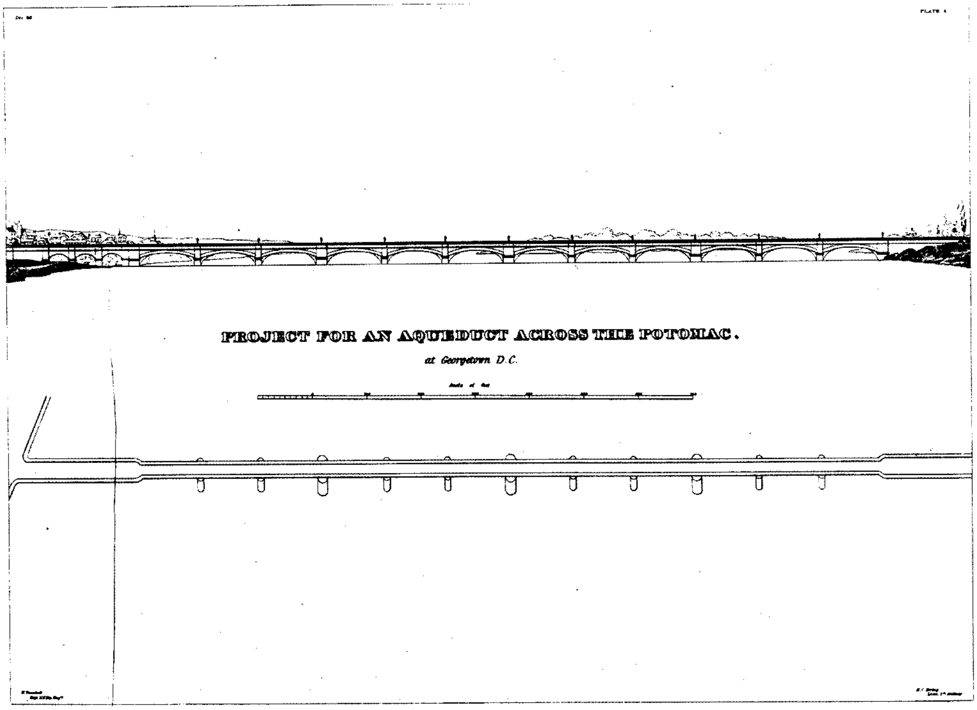

Figure 3
Original design of the Potomac Aqueduct. The Potomac Aqueduct was originally designed as a traditional masonry arch structure of twelve spans. Because of a shortage of funds, the Directors of the Alexandria Canal Company decided on a wooden superstructure instead of the masonry superstructure shown here. The three spans on the Virginia side (right) were deleted in favor of a causeway. Georgetown is shown on the left. Drawing by Captain William Turnbull and Lieutenant M. C. Ewing. «Project for an Aqueduct Across the Potomac.» (Turnbull 1838, Plate 4)

sections and held together with iron dogs. In essence, the circular coffer dam was a single row of vertically mounted beams without cross bracing of any kind. Further, Martineau made no provision to seal this structure through the use of clay puddling or other material. See Figure 4.

Turnbull and the other engineers objected to Martineau's approach for cofferdam construction. But because of Martineau's engineering reputation, the Board of Directors of the Alexandria Canal Company decided to award the contract to him. On June 29, 1833, the Alexandria Canal Company signed a contract with Dr. Martineau to construct the piers and south (Virginia) abutment. The first pier to be constructed was pier number one, adjacent to the Virginia shoreline.

Martineau delayed in proceeding with the contract. It was not until September 2, 1833, that the work for the circular cofferdam was let. By September 26, 1833, the circular frame for the cofferdam was towed into position over the site of the future pier number one. Bad weather intervened. The cofferdam was not weighted down and sunk until October 2, 1833. Only one pile driver was employed and it was not until November 16, 1833 that all the piles had been driven securing the circular cofferdam in place (Turnbull 1838, 6).

The next step was to pump the water out of the cofferdam so construction could proceed. The contractor constructed a platform on piles adjacent to the circular cofferdam but just downstream. On this platform the contractor mounted a 20 horsepower

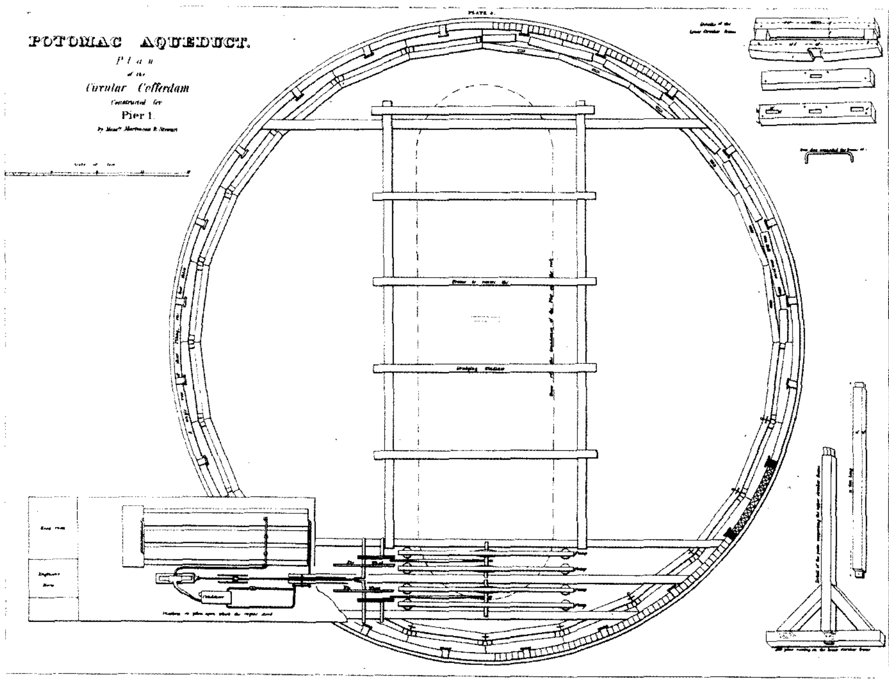

Figure 4
Plan of Circular Cofferdam. In January 1833, the Alexandria Canal Company advertised for bids for the designed aqueduct. Martineau and Stewart proposed the use of circular cofferdam for pier construction. Over the objections of Turnbull and other engineers, the company accepted the proposal. A circular cofferdam was constructed for Pier Number 1 but could not keep the water out. It was destroyed by an ice storm in December 1833. «Potomac Aqueduct Plan of the Circular Cofferdam Constructed for Pier 1.» (Turnbull 1838, Plate 5)

steam engine (20.3 horsepower metric). This steam engine powered eight pumps capable of raising 500 cubic feet of water per minute (236 liters per second).

On December 13, 1833, the contractor began pumping out the circular cofferdam. After an hour of work, the water within the cofferdam had risen 8–1/2 inches (21.6 cm) —equal to the rise of the tide outside the cofferdam. Clearly, without puddling the circular cofferdam could never be emptied of water (Turnbull 1838, 6).

At this point winter intervened. On December 21, 1833, the circular cofferdam was crushed by a flood accompanied by ice. The contractor showed no desire to repair his work and on January 4, 1834, the Alexandria Canal Company declared the contract had been abandoned and directed Captain Turnbull to vigorously press forward on the work.

The Second Attempt —Captain William Turnbull— 1834

Turnbull's first step was to contract for the necessary equipment to build the Potomac Aqueduct's piers. His first contract was for two steam engines to power the pumps needed to empty the cofferdam he intended to construct. He also contracted for building two scows upon which these steam engines were to be mounted.

It was Turnbull's intention to build two piers a year, requiring a total construction time of four years for all eight piers (not including construction time needed for the two abutments). To do this, Turnbull needed more pile drivers. He contracted for the construction of three pile drivers: two heavy duty pile drivers for driving the oak piles and one light duty pile driver for driving the sheeting. The heavy duty pile drivers were to be worked by horses and the light pile driver to be worked by a tread wheel. He had Martineau's and Stewart's pile driver, worked by a crank, repaired. This gave him a total of four pile drivers for the work.

Turnbull also contracted for an excavating machine. This machine, it was intended, would excavate the mud in the bottom of the cofferdams and transport that mud to the top of the cofferdam for transfer to waiting scows.

Finally, Turnbull contracted for sixteen pumps, each made of wood and thirty-eight feet (11.6 m.). They were made of eight white pine wooden staves, three inches (7.6 cm) in thickness. Inside the «barrel» was eighteen inches (45.7 cm) in diameter. These wood staves were banded by iron bands and their joints sealed by narrow slips of cotton cloth coated with white lead.

Building the Cofferdam for Pier Number Two —1834

On March 4, 1834, Turnbull's crew had pulled the first pile of what remained of Martineau's and Stewart's circular cofferdam. By March 26th the entire structure had been removed.

Turnbull had decided to begin his work at the site of the future pier number two, adjacent and north of pier number one where Martineau and Stewart had worked. At this location bedrock could be found under eighteen feet of water (5.5 m.) and a little over seventeen feet of mud (5.2 m.).

Turnbull's plan for a cofferdam was a box within a box. In plan view, this was a parallelogram with a parallelogram (See Figure 5). The outer parallelogram was approximately 116 feet long (35.4 m.) by 61 feet long (18.6 m.), out to out. The inner parallelogram was approximately 84 feet long (25.6 m.) by 29 feet wide (8.8 m.), out-to-out. The space between the inner and outer parallelogram, approximately fifteen feet on all sides (4.6 m.), was where the clay puddling would be tamped into place. It was this clay puddling, long used as a sealer on canal prisms, which Turnbull intended to use to seal the water out of the cofferdam.

The inner wall of the cofferdam was formed of pilings of oak that were forty feet long (12.2 m.) and 16 inches in diameter (40.6 cm). They were spaced at four feet on center around the perimeter of the inner wall. These pilings were iron shod, pointed with steel, and were driven to bedrock using a ram weighing 1,700 pounds (771 kg.) dropped forty feet (12.2 m.). The pilings were tied together by means of a stringer of pine, one foot square (30.5 cm), each piling bolted to the stringer.

The outer wall of the cofferdam was also formed of pilings of oak that were thirty-six feet long (10.9 m.) but not shod with iron and not driven to bedrock. Not driving these outer pilings to bedrock was later found to be an error —the pressure of the water forced sand and water to enter the cofferdam under these pilings. But this was not known at this time. Like the inner wall, these outer pilings were secured to a stringer as described above (see Figure 5, plan view) (Turnbull 1838, 8).

Scaffolding was installed on top of the oak pilings, to hold the pile drivers for the sheeting piles. The sheeting piles were then added. The inner box sheeting piles were forty feet long (12.2 m.) and six inches thick (15.2 cm) and the outer sheeting piles were thirty-six feet long (11 m.). They were formed, using bolts, into sixteen foot long panels (4.9 m.), called montants, and driven into the mud with two pile drivers with a 1,300 pound ram (590 kg.) dropped forty feet (12.2 m.).

Turnbull provides us with some data on driving sheet piles. The tread-wheel pile driver was found to be the most superior. The crank powered pile driver required eight men and a superintendent and were able to drop the ram from the top of the planes, forty feet above (12.2 m.) every seven and a half minutes. The tread-wheel powered pile driver only required six men and a superintendent and made a blow from the same height and same weight (1,300 pounds, 590 kg.) every minute and fifteen seconds. The horse powered pile drivers were able to deliver a blow every minute and fifteen seconds.

Next, Turnbull tied together the outer parallelogram with the inner with the use of ties of eleven inches square (27.9 × 27.9 cm) pine members spaced every twelve feet (3.7 m.). But when the clay puddling was added to the space between the inner and outer boxes, these ties were found insufficient. Turnbull had to add ties for every other oak pile and strengthen the lateral stability of the structure through other means.

With the inner and outer structures secure and with the clay puddling in place inbetween, the next step was to begin the pumps to empty the cofferdam of

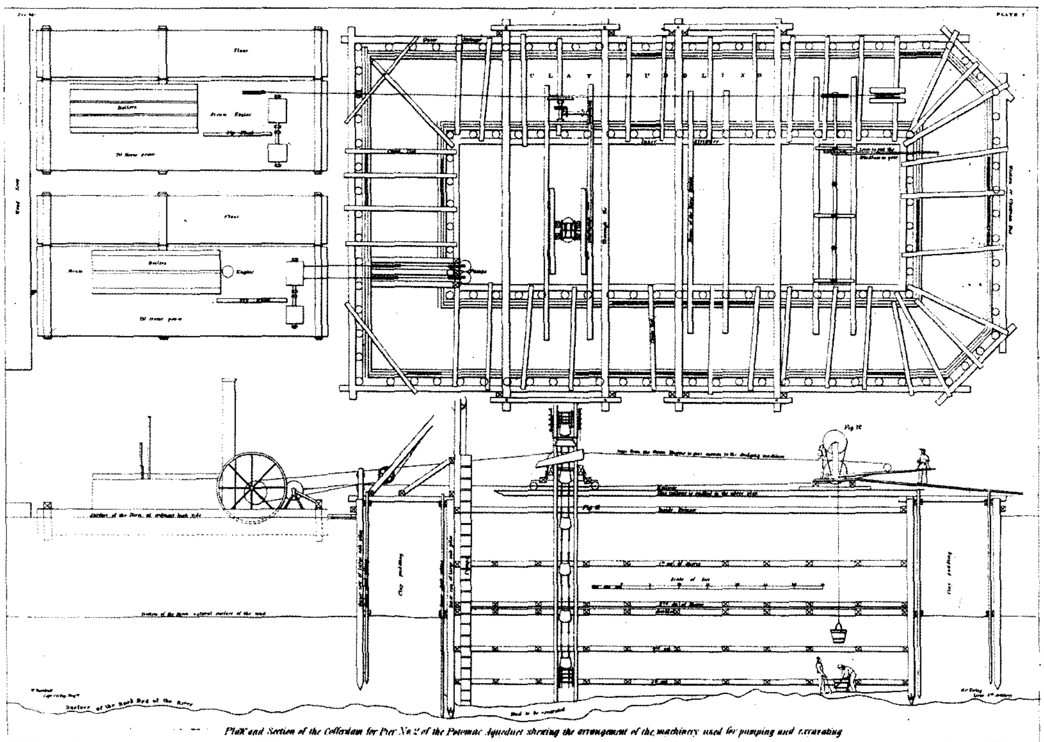

Figure 5
Plan and Section of Turnbull's Cofferdam. In January 1834 Captain William Turnbull took over the construction of the Potomac Aqueduct. He designed a rectilinear cofferdam consisting of a box within a box. Between the outer box and the inner box, Turnbull used tamped puddling as a water sealer. Shown in this plan and section are the scow mounted steam engines used to power the pumps and the excavating machine. Shown in the section are the outer piles which were not driven to bedrock. This later would prove a problem as the water pressure outside the outer box would force water, sand and mud up and under these outer pilings. Drawing by Captain William Turnbull and Lieutenant M. C. Ewing. «Plan and Section of the Cofferdam for Pier No. 2 of the Potomac Aquecut showing the arrangement of the machinery used for pumping and excavating.» (Turnbull 1838, Plate 7)

water so that excavation could commence. Turnbull began the pumps on September 2, 1834 with less than satisfactory results. Ropes stretched and straps broke. Other things went wrong. Turnbull wrote:

> So frequently were accidents happening to the machinery and pump gearing, that the time of pumping in each day rarely exceeded the time noted above (about fifty minutes) (Turnbull 1838, 11).

Slowly Turnbull and his men began to improve the efficiency and reliability of the pumps and the steam engines. The water began to be lowered in the cofferdam. But then it was discovered that the cofferdam structure had to be again strengthened against the outside water pressure. By mid-September 1834, the cofferdam for Pier Number 2 had been entirely emptied of water.

Excavation of the Cofferdam at Pier Number Two —1834

By October 2, 1834, Turnbull was ready to try the excavating machine that he had constructed. The machine, an endless series of buckets driven by a steam engine in a scow along side the cofferdam, worked well under no load. But when subject to the resistance of the mud to be excavated and the weight of the mud to be carried to the top of the cofferdam, it worked only with great difficulty. Further, to be used as an excavator, it had to be lifted over the shores installed in the cofferdam, a difficult and lengthy proceeding. Turnbull abandoned the idea of using the machine as an excavator and instead used it as an elevator for mud hand dug by laborers. A steam driven windlass, capable of hauling four buckets of 4.6 cubic feet each (0.13 cubic meters), was also used to hoist mud to the top of the cofferdam as was the horse driven pile driver, now converted into a mud hoist machine.

By October 22, 1834, laborers had excavated six feet of mud out of the cofferdam. But then it was discovered that several oak piles on the south side of the cofferdam had failed and that failure had increased pressure on the cross braces at the end which caused them to crack also. While Turnbull was moving to shore up this failure of the cofferdam, a major leak was discovered in the northeast corner of the cofferdam. The pressure of water outside the cofferdam forced the mud under the foot of the outside or «montant» piles which had not been driven to bedrock. The clay puddling soon stopped the leak. After this leak, Turnbull had his men operating the pumps to eliminate the water that had entered the cofferdam. The crank wheel of the steam engine broke halting pumping operations. It was soon replaced.

More troubles plagued construction of Pier Number 2. On November 3, 1834, a large leak developed filling the cofferdam with water. Sand accumulated around the pump in the cofferdam resulting in additional strain on the rope and engine which caused the crank-shaft to break. The engine was repaired and excavation within the cofferdam continued. On November 15, 1835, in the midst of an early winter storm, the workers refused to go to work and stayed off work for several days. The storm caused several of the construction scows to break their moorings and be swept to shore. Leakage continued in the cofferdam and pumping machinery continued to fail, probably because of the extremely cold weather experienced. Despite these setbacks, Turnbull was able to reestablish the stability of he cofferdam and was able to reach bedrock through the mud. Fifteen cubic feet of masonry (0.42 cubic meters) was set in hydraulic cement by the beginning of January. By that time, January 4, 1835, Turnbull had to close down construction operations for the winter and secure the cofferdam and equipment. (Turnbull 1838, 15–18).

Instead of being discouraged by the setbacks of 1834, Turnbull was encouraged that he could prevail. Gradually he and his men had been improving the efficiency and reliability of their equipment. They had learned lessons that would allow more efficient cofferdams for the remaining piers, such as driving the outer pilings to bedrock. Through trial and error they had also learned how to construct a cofferdam that would resist the experienced water pressures.

The 1835 Construction Season

The 1835 construction season started late, in April, due to a delay in securing adequate funds to support construction operations. The first work to be done, beginning on April 22, 1835, was to strip the winter covering off of cofferdam number 2. The pumps were then put back in place, as were the steam engines and the windlasses (needed for hoisting out a small amount mud in the cofferdam).

The immediate need was to implement a system for unloading stones from the scows —stones that weighed from three to four tons each (2722 to 3629 kg.)— lift them to the top of the cofferdam, and then lower them into place in the pier under construction. Lieutenant Bartlett devised such a system for Turnbull. Two railways, consisting of twelve inch square (30.6 cm square) members were placed parallel to each other and securely fastened to the oak piles. On the inner surface of these rails, flat irons were fastened. Carriages were built on top of these. One end of the carriages extended ten feet over the edge, and was reinforced with braces of iron. On top of the carriages were mounted a derrick and on the derrick a winch. The derrick was mounted on wheels allowing travel across the top of the cofferdam. The derricks were operated by four men and a boy. This device thus allowed the derrick to travel over to the edge of the cofferdam, lower a rope to the waiting scow, have a stone of from three to four tons (2722 to 3629 kg.) attached, winch the stone up to the top of the derrick, travel back to the appropriate

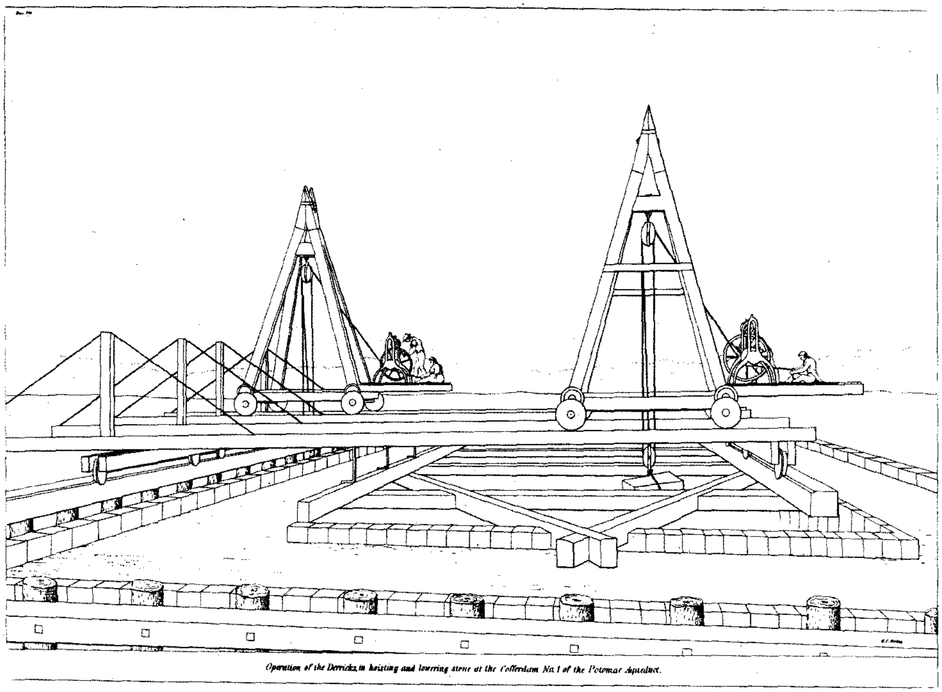

Figure 6
Derricks, Winches and Railway for delivering stone to masons in the Cofferdam. At the beginning of 1835 Turnbull had designed a system to off load three to four tons (2722 to 3629 kg.) stone from scows, lift them vertically to the top of the cofferdam, transport them horizontally across the top of the cofferdam and then lower the stone to the masons working in the cofferdam below. Drawing by Lieutenant M. C. Ewing. «Operation of the Derricks in hoisting and lowering stone at the Cofferdam No. 1 of the Potomac Aqueduct.» (Turnbull, 1838)

position and thus lower the stone to the construction work inside the cofferdam. The two railways, described above, permitted the two derricks to travel longitudinally along the length of the cofferdam. See Figure 6 and Figure 7. (Turnbull 1838, 19).

Special care was taken with the mortar used in the piers. Hydraulic cement was used up to the two foot mark (0.6 m.) above high-water mark, above that common lime mortar was used.

Unlike the excavation work undertaken in the previous year, the masonry work of pier number 2 went quite fast. By June 21, 1835, the masonry of the pier was up to the top of the cofferdam. At this time the derricks and railways, described above, were removed and two booms were installed to assist in constructing the pier to twenty-nine feet (11.1 m.) above high-water. See Figure 8.

With the masonry at the top of cofferdam number 2, it was obvious to all that Turnbull and his engineers had been successful in developing techniques to build piers in deep water conditions. In celebration of this victory, the President of the United States, Andrew Jackson, and his cabinet visited the construction site of pier number two in June 1835 (Turnbull 1838, 20).

Completion of the Potomac Aqueduct —1835 to 1840

Once the techniques of cofferdam construction, pump construction and masonry handling had been worked out on Pier Number 2, construction on the rest of the aqueduct could proceed with few problems. Turnbull wrote of his accomplishment:

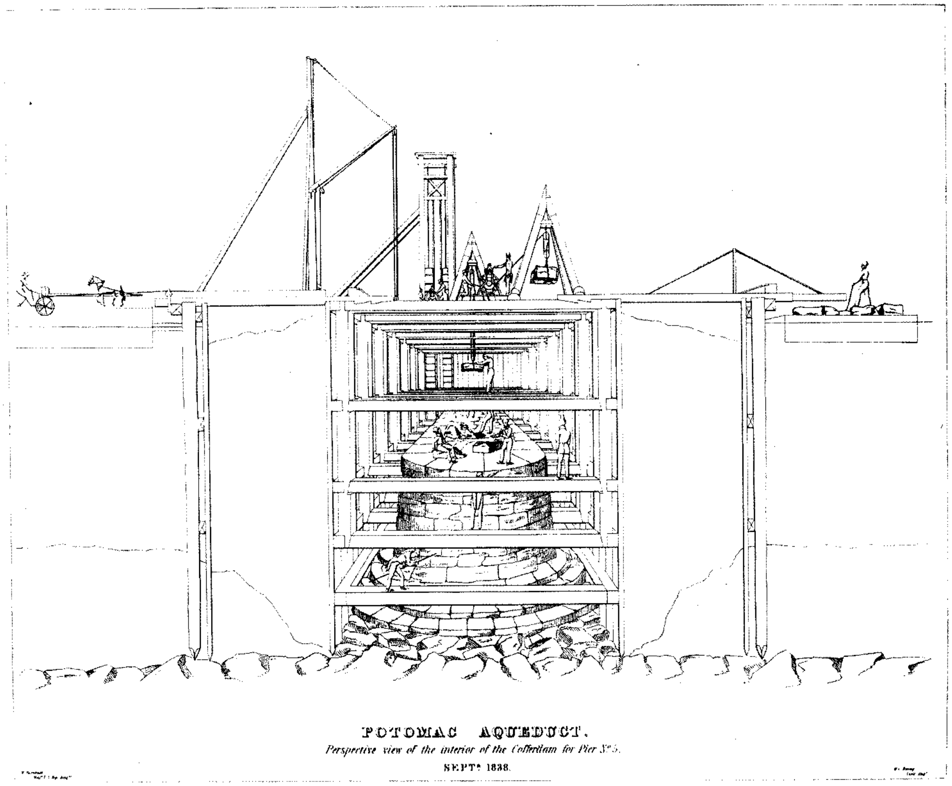

Figure 7
Interior view of pier construction within the Cofferdam. Interior view of the cofferdam showing masonry work and the delivery system of derricks, winches and railway. This perspective was drawn for Pier Number 5. Note that, unlike Pier Number 2, the outer pilings have been driven to bedrock. Also note the dress of the workmen, particularly their top hats. In the early nineteenth century skilled workers frequently dressed well for construction. Drawing by Captain William Turnbull and Lieutenant M. C. Ewing. «Perspective view of the interior of the Cofferdam for Pier No. 5.» (Turnbull, 1838)

> When I reflect upon the numerous difficulties which we have overcome in the progress of the work, and recall the disheartening predictions of that numerous portions of the community who looked upon the attempt to establish foundations at so great a depth, and in a situation so very exposed and dangerous, and who did not fail to treat it as an absurdity, I cannot but congratulate myself upon having so happily succeeded . . . (Turnbull 1841, 35)

Turnbull had constructed one of the longest bridges in America at that time (Mahan 1846, 225). Turnbull had developed a practical approach to pier construction in deep water conditions. This approach was well illustrated by Turnbull and Ewing's drawings and widely distributed through U.S. Government reports. By the time these reports appeared, the American railroad revolution was in full swing and these techniques were used by railroad builders to extend their railroads westward.

Aftermath —The Potomac Aqueduct— 1840 to 2002

In the years 1840–1843, a wooden superstructure was added on top of the masonry piers to carry the Alexandria Aqueduct from the Chesapeake and Ohio Canal in Georgetown to Alexandria, Virginia (See Figure 9 and Figure 10). The Chesapeake and Ohio

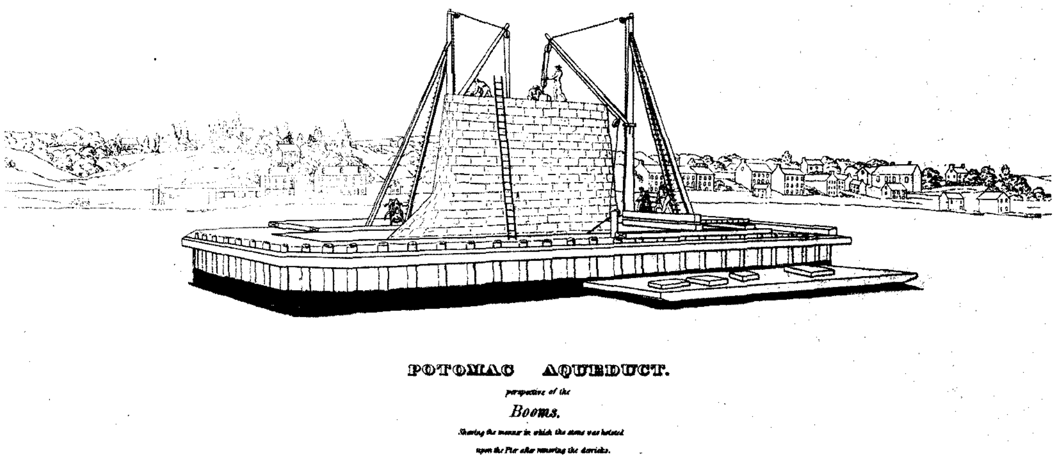

Figure 8
Booms. Once the masonry was above the top of the cofferdam, the derricks, winches and railways were dismantled. Booms were then erected to continue the work of constructing the masonry piers. Drawing by William Turnbull and Lieutenant M. C. Ewing. «Perspective of the Booms Showing the manner in which the stone was hoisted upon the Pier after removing the derricks.» (Turnbull 1838, Plate 15)

Canal itself reached Cumberland, Maryland, some seven years later. Like its larger cousin, the Alexandria Canal saw modest traffic but failed to live up to the expectations of its developers. By its opening in 1843, it was apparent that the future of American transport was with railroads.

With the onset of the Civil War in 1861, the Potomac Aqueduct was drained of water and used as a military vehicular bridge across the Potomac. Following the Civil War, in 1868, the wooden superstructure was replaced by another wooden structure. The new structure was two stories, with road on top and canal on the bottom. In 1888 this second wooden structure was replaced by a metal truss structure that served as a highway bridge. In the early 1920s, the present reinforced concrete arch highway bridge, Key Bridge, was constructed immediately south of the Potomac Aqueduct (Myer 1975). Almost immediately after the opening of Key Bridge, by 1926, the Army was pressing Congress for funds to tear down the old Potomac Aqueduct at a cost of $228,000 (U.S. House, 1926). After World War II the Army received funds to tear down most of the piers of Potomac Aqueduct. Not destroyed were the abutment at the Chesapeake and Ohio Canal, now under the administration of the Chesapeake and Ohio Canal National Historical Park, and a remnant of Pier Number One on the Virginia side.

Summary and Conclusions

What Turnbull had accomplished was pier construction of the Potomac Aqueduct at a deep water crossing. This had been accomplished before in the United States and elsewhere, notably the Market Street Bridge in Philadelphia discussed by Turnbull. But the real significance of Turnbull's accomplishment was the publication of a detailed account, accompanied by the remarkable drawings prepared by him and Lieutenant Ewing, of the construction process of building the piers for the Potomac Aqueduct. This publication came when American engineers were building American railroads westward and faced major river crossings. The report became a manual of construction on how

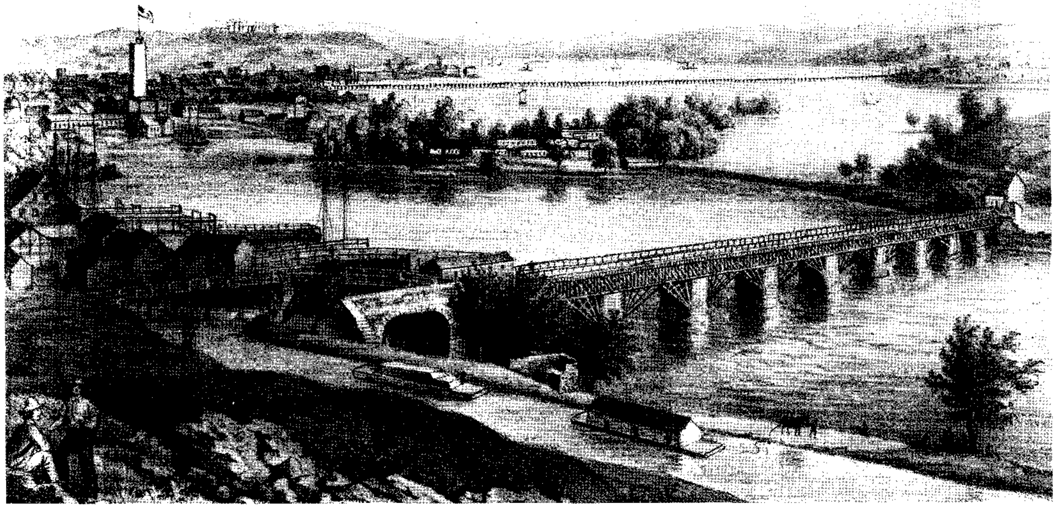

Figure 9
View of completed Aqueduct with wooden superstructure. View of the Potomac Aqueduct from Georgetown, looking south along the Potomac River. The Chesapeake and Ohio Canal can be seen at the bottom of this drawing. The partially completed Washington Monument can be seen on the left side of the drawing. Analostan Island, now called Theodore Roosevelt Island, can be seen in the middle of this drawing. At the time of this photograph the Potomac Aqueduct was dewatered and being used as a military bridge across the Potomac River. Drawing by F. Dielman, 1854. «Aqueduct of Potomac, Georgetown, D.C.»

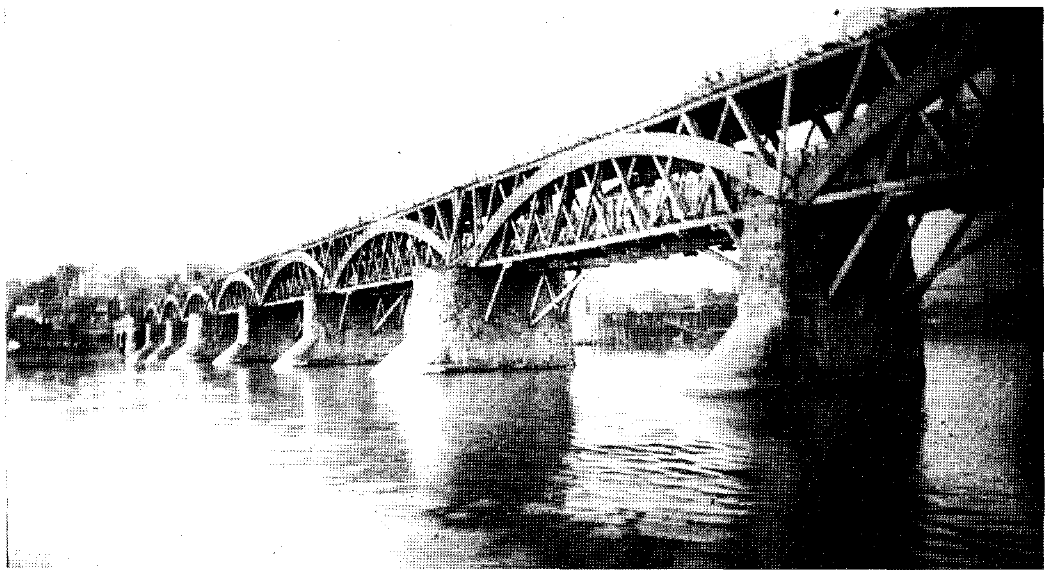

Figure 10
Photographic view of Potomac Aqueduct. View of the Potomac Aquecut, second wooden superstructure in place. Georgetown is behind the aqueduct. Photographed 1868-1877, photographer unknown. Georgetown Public Library

to build railroad bridges across the wide and deep American rivers. This was the reason that his remarkable report was republished by the Department of the Army in 1873 —thirty-five years after completing the construction of these aqueduct piers.

By the end of the nineteenth century, Turnbull's reports would be forgotten. Larger and deeper rivers would have to be crossed. Caisson technology would replace cofferdam techniques. Manufactured iron and steel pumps would replace wooden ones. Structural calculations would replace Turnbull's empiricism. Machine driven pile drivers would replace horse powered pile drivers. Nonetheless, Turnbull's reports of building the Potomac Aqueduct are still of great interest to the historian of construction as the most comprehensive description of an early American engineering construction project.

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