History Uncovered

After a flood ravaged a late-19th-century covered bridge in Lancaster County, Pennsylvania, it took a team of engineers and builders months to inspect the damage and devise a plan to salvage or replace each water-logged member. The result is a new bridge built with 19th-century techniques that accurately re-creates a local treasure.

By Dave Hoglund, P.E.

In September 2011 rising waters generated by the tropical storm Lee forced the 127-year-old Siegrist's Mill Covered Bridge from its abutments and swept it downstream, *right.* Nearly two years later, the bridge had been reconstructed using designs and techniques common to the late 19th century, the time when it was built. Covered bridge enthusiasts came from many locations to observe the salvaging of the original bridge, the placement of the reconstructed frame, and the ribbon-cutting ceremony.

COURTESY OF LANCASTER COUNTY; *INSET:* KEN STANEK PHOTOGRAPHY, COURTESY OF RETTEW

As part of the project the engineers improved the safety of the bridge and its approaches by adding guardrails to the reinforced-concrete wing walls, adding drainage inlets to the roadways, and widening turning areas along the road so that oversized and overweight vehicles could turn around.

KEN STANEK PHOTOGRAPHY, COURTESY OF RETTEW, *BOTH*

IN EARLY SEPTEMBER 2011 the tropical storm Lee developed off the Gulf Coast and slowly meandered through Louisiana, Mississippi, Alabama, and the Florida Panhandle. It then moved up the Atlantic coastline, its large size and leisurely pace causing historic flooding in such states as New York and Pennsylvania. Still recovering from Hurricane Irene, which had struck in August, residents of Lancaster County, Pennsylvania—many of them members of the Amish and Mennonite communities who rely on the horse and buggy for transportation—watched as an additional 15 in. of rain fell. The deluge eventually forced the 127-year-old Siegrist's Mill Covered Bridge from its abutments and swept it downstream.

Less than two years later the bridge's owner, Lancaster County, in cooperation with the local engineering firm RETTEW Associates, Inc., managed a complete restoration of the historically important timber bridge. The team used 19th-century construction details in conjunction with modern engineering and construction methods to return the bridge, which is both a critical facet of infrastructure and a local landmark, to the community.

Siegrist's Mill Covered Bridge crosses Chiques Creek in the western part of Lancaster County, which is in the southeastern part of Pennsylvania, and it is among the oldest of the 20 county-owned covered wooden bridges that are hallmarks of the region's history. Built in 1885, the structure was originally named Michael Moore's Mill Bridge after the owner of a nearby mill. The Siegrist family gained ownership of the mill a few years later and renamed the bridge. The structure was also affectionately known as the Scripture Bridge, as locals would often climb under it and attach homemade wooden plaques bearing Bible verses to the floor beams and lower truss members. In 1980 the structure was listed in the National Register of Historic Places.

Constructed by James C. Carpenter, a famed covered bridge builder of the era, Siegrist's Mill Covered Bridge was one of the few covered bridges in the area to survive Hurricane Agnes, which struck in 1972, although it was flooded by 5 ft of water. Referred to as a Burr arch truss design in honor of the 19th-century American bridge builder Theodore Burr, the structure combines the rigidity of a truss with the bearing capacity of an arch and is the structural system

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employed in all of Lancaster County's covered bridges. Used by pedestrians and many avid cyclists in the region, as well as by horse-drawn wagons and motor vehicles, the one-lane bridge connects the townships of Rapho and West Hempfield and from a historical standpoint is regarded as a treasure.

As joints loosened, timber decayed, and members broke over time, county maintenance staff performed repairs to keep the bridge in service. These repairs, while functional, detracted from the appearance and significance of the structure. The bridge was slated for refurbishment in the county's long-term maintenance plan, but the tropical storm in 2011 accelerated matters.

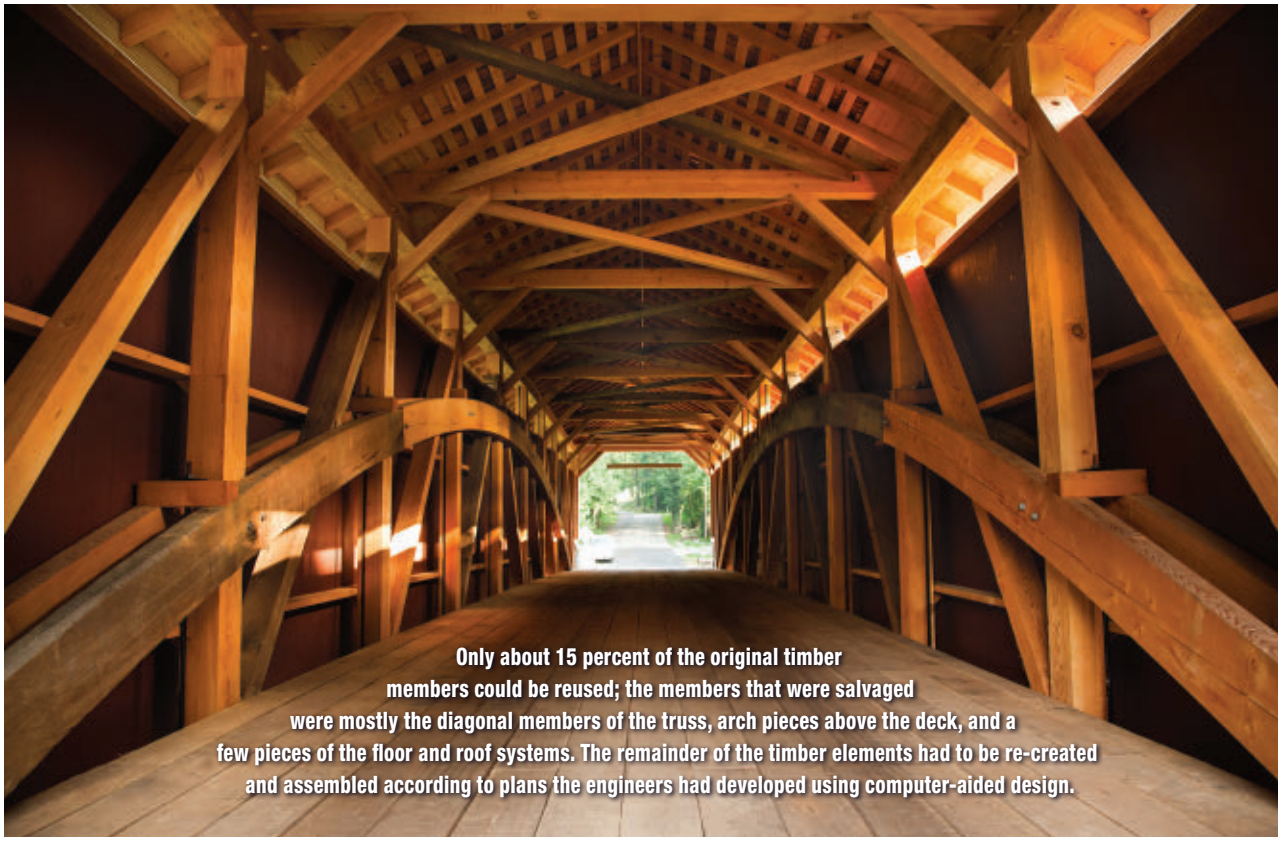
After the waters of Chiques Creek receded in September 2011, the structure, which had come to rest on an embankment 100 ft downstream, was safely stabilized and inspected. The structure had sustained extensive damage, but the extent of the harm was not fully visible because the bridge was partially submerged. The county braced the structure with cables and tie-down straps to hold it together to the fullest extent possible until it could be moved. The team also anchored the bridge to the embankment to minimize the possibility of it being washed downstream by another storm.

Lancaster County issued a contract to Abel Construction Co., Inc., of Mountville, Pennsylvania, for the removal of the bridge from the creek. The county planned to place the bridge on a newly constructed level pad in a nearby meadow. There it could be thoroughly evaluated, and the team could formulate a reconstruction strategy. Working with Abel Construction, the county's team cut holes in the roof that would enable the rigging from the cranes to connect to and lift the bridge. The locations of the pick points duplicated the member forces present when the bridge was on its abutments. Abel Construction and Lancaster County reinforced any suspect primary structural connections to ensure that the bridge could sustain its own dead load. Cranes then lifted the bridge from the creek and placed it on the temporary pad on October 18, 2011, at which point a comprehensive evaluation of the structure began.

Over a period of two weeks RETTEW engineers performed a detailed inspection of the structure. The goals of the inspection were to assess the condition of the recovered members to determine if any of them were suitable for reuse and to record the dimensions of each member so that reconstruction plans could be developed. RETTEW's engineers measured the entire bridge to ensure the sum of the individual members matched the length of the whole structure. However, many of the members were either missing or so severely damaged that RETTEW could not develop accurate plans in this way. Consequently, the firm relied on its survey department to accurately establish the locations of the abutment seats, thereby resolving the differences caused by the missing or damaged members. Bridge engineers with RETTEW sketched the connection details for inclusion in the reconstruction plans, and investigations by in-house archaeologists and cultural resource professionals ensured that the details would be historically accurate. Some of the bridge connections were reinforced with steel members and were obviously not part of the original bridge, but others required more investigation.

View a video of this project at www.asce.org/cemagazine or www.asce.org/ceapp.

After documenting the dimensions of every member, RETTEW began determining which members would be



Only about 15 percent of the original timber members could be reused; the members that were salvaged were mostly the diagonal members of the truss, arch pieces above the deck, and a few pieces of the floor and roof systems. The remainder of the timber elements had to be re-created and assembled according to plans the engineers had developed using computer-aided design.

suitable for reuse. When Lancaster County rebuilds one of its covered bridges, it seeks to reuse as much of the original timber as possible. This measure results in cost savings and also preserves the character and authenticity of the structure. RETTEW used timber probing tools—primarily awls—to determine if any of the members that were still intact were rotten, split, or soft. Since the bridge was for the most part intact, RETTEW was not able to inspect the ends of every member since some formed part of embedded connections. Rather than use complex methods of investigation or disassemble the structure, RETTEW simply added a specification to the construction contract allowing, upon disassembly, the replacement of any deteriorated structural members as a change order to the contractor's construction agreement.

Once the inspection team completed the documentation of the structure, the engineers started assembling the structure digitally in a virtual environment via computer-aided design (CAD) to ensure that all of the reused and new pieces would fit together with tight connections. By undoing the repairs that had been carried out in the years since the bridge's construction, the team was able to create a bridge that would be not only stronger but also more historically accurate. For example, pieces of the vertical truss members extending below the bottom chord broke off as time passed. Locals patched the connections together with metal strapping and bolts. RETTEW detailed the connections on the new bridge to be a timber-only detail, as was originally constructed at the site.

After assembling the superstructure of the bridge through CAD, the designers positioned the CAD image over the survey images of the abutments to determine the dimensions of the missing or damaged end pieces. The superstructure plans were complete at that point.

Because the bridge is a valued local landmark and has received national attention, Lancaster County wanted to implement every measure available to minimize the possibility of the structure being damaged again by a flood. The engineers investigated various options by reviewing the floodplain and came to the same conclusion reached by other bridge builders past and present: raising the bridge would be the most cost-effective means of minimizing future damage. RETTEW investigated the history of Chiques Creek's flows, water surface elevations, and flood-induced structural damage over the past 50 years. On the basis of statistical data the team determined that if the bridge were raised by 2 ft, the new height would save one full reconstruction every 100 years. The Federal Emergency Management Agency, which provided most of the funding for the project, concurred with RETTEW's analysis and agreed to cover up to 50 percent of the reconstruction cost.

Since the original abutments were constructed mainly of stones that had been "dry stacked," that is, put in place without mortar, the engineers were unsure of the abutments' composition and stability and thus were not comfortable with the idea of raising the bridge. The stones farther down the abutment stem were much larger and were seen as forming a solid foundation for new abutments. So RETTEW designed reinforced-concrete cantilever abutments to be placed atop the solid foundation to support the new covered bridge. Unlike a standard cantilevered bridge abutment, a covered bridge cantilevered abutment requires not one but four seats: a sloped seat that accepts the timber arch and level seats for the bottom chord, the stringers, and the top of the back wall, which is flush with the deck.

The new abutments had to blend with the remaining abutment walls and the built environment of the surrounding area. RETTEW specified a stone masonry facade on the interior and exterior walls of the abutments, and recessed sections of the concrete walls were detailed to accept the stone facade.

The engineers specified a stone masonry facade for the interior and exterior walls of the new abutments so that the walls would blend with the remaining abutment foundations and the environment of the surrounding area.

Other decorative features noted in RETTEW's plans included the reuse of the scripture plaques that had been salvaged from the bridge and the use of a cedar shake roof for the structure. Typically, a standing-seam metal roof is recommended in a shaded setting because shade accelerates moss growth on shakes, which leads to frequent and costly roof replacements. For this bridge, however, so much of the surrounding tree canopy had been removed during the crane operations to lift the bridge out of the creek and then place it on the new abutments that sunlight would now strike the shakes during most of the day, keeping moss growth to a minimum.

RETTEW worked with various federal, state, and local permitting agencies on the reconstruction of the bridge. Emergency disaster relief funding for the project came not only from the Federal Emergency Management Agency

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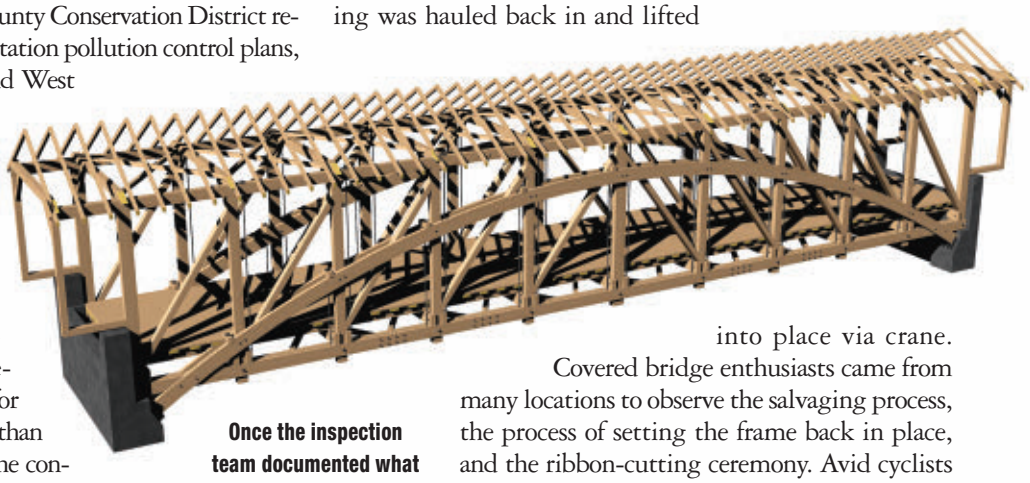
but also from the Pennsylvania Emergency Management Agency. The U.S. Army Corps of Engineers, in partnership with the Pennsylvania Department of Environmental Protection, granted a permit for the structure under a joint permit application process that was required because RETTEW intended to raise the bridge and place a corresponding amount of fill within the floodplain. The Pennsylvania Historical and Museum Commission reviewed RETTEW's plans for the bridge and provided insight into and approval of the historically accurate design. The Lancaster County Conservation District reviewed the erosion and sedimentation pollution control plans, and the townships of Rapho and West Hempfield reviewed the floodplain and storm-water plans for the project.

Bulldog Construction Co., Inc., of Coatesville, Pennsylvania, in cooperation with Lancaster County Timber Frames, Inc., of York, Pennsylvania, used RETTEW's designs to rebuild the structure for $803,149.45, significantly less than the budgeted amount. While the construction of the abutments was under way on-site, the framers disassembled the timber bridge and transported the pieces to a warehouse facility at which they could be refurbished in a controlled environment so as to increase efficiency during construction. The members that were salvaged for reuse were for the most part the diagonal members of the truss, arch pieces above the deck, and a few pieces of the floor and roof systems. These were the only members that could be reused, and they represented no more than 15 percent of the total. The remaining bridge members were either too badly damaged from the flood or too rotten from sitting in the creek.



Once the inspection team documented what remained of the original bridge, the engineers started assembling the structure digitally through computer-aided design. This ensured that all of the reused and new pieces would fit together and that the bridge would fit onto the abutments.

Not only were the timber members revitalized and replaced, but Lancaster County Timber Frames also took it upon itself to refinish and repaint the scripture plaques that had adorned the underside of the bridge.

As an additional part of the bridge restoration project, RETTEW's engineers provided numerous improvements to the site. Because of the region's rolling hills, most covered bridges in Lancaster County feature steep approaches that create blind spots for approaching vehicles. In addition to raising the bridge, RETTEW improved the sight distance for this bridge by elevating the approach roadway and clearing away roadside obstructions. It also provided wider turning areas along the road so that oversized and overweight vehicles would be able to turn around. The roadway design called for drainage inlets to be added in areas that typically experienced ponding. RETTEW's engineers also added standard approach guide rails to the reinforced-concrete wing walls to prevent blunt-end impacts.

RETTEW has designed and managed other covered bridge reconstruction projects, but this one was unique. With so many stakeholders involved in Siegrist's Mill Covered Bridge, RETTEW's engineers worked diligently to navigate and smoothly manage the communication between all parties and learned how to better manage projects when a variety of agencies and stakeholders are involved.

The community was very involved in both the reconstruction process and the bridge's reintroduction. A nearby landowner allowed his land to be used so that crews could lift the bridge out of the creek and then deconstruct it. Local property owners also worked with the contractor as the finished framing was hauled back in and lifted into place via crane. Covered bridge enthusiasts came from many locations to observe the salvaging process, the process of setting the frame back in place, and the ribbon-cutting ceremony. Avid cyclists and runners also are pleased to have the landmark back in place. Covered bridges are an important part of the tourism industry in Lancaster County, and the reconstructed Siegrist's Mill Covered Bridge can now continue to support the local economy.

The project took almost two years to complete—about one year for design and another nine months for construction. The bridge opened to pedestrian and vehicular traffic in June 2013, and the county held a ribbon-cutting ceremony the following month.

The complexities of restoring Siegrist's Mill Covered Bridge required finesse to knit together the design, management, and preservation aspects. This bridge is a prime example of a type of engineering that is slowly disappearing in our fast-paced culture. By working with communities, engineers can apply their expertise to maintain such structures as covered bridges in a way that will meet transportation needs while honoring achievements of the past. **CE**

Hoglund

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PROJECT CREDITS **Owner:** Lancaster County, Pennsylvania **Structural engineer, geotechnical consultant, civil engineer, and construction manager:** RETTEW Associates, Inc., Lancaster, Pennsylvania **Construction firm:** Bulldog Construction Co., Inc., Coatesville, Pennsylvania **Framer:** Lancaster County Timber Frames, Inc., York, Pennsylvania **Bridge removal:** Abel Construction Co., Inc., Mountville, Pennsylvania

LANCASTER COUNTY TIMBER FRAMES, INC.