A Total Systems Approach

Large repair projects can require far more than engineering the repairs themselves

by Bill Hoffmann

Over the course of an engineering professional's career, certain projects develop into benchmarks that inform the best course of action and inspire effective solutions for countless assignments to come. Such is the case with the rehabilitation of the landmark 2.8 mile (4.5 km) long levee along the Arkansas River in Pueblo, CO.

Unique Approach to a Unique Project

After the Arkansas River flooded Pueblo in 1921, the city built a levee to protect its downtown—three-quarters of which lies within the river's floodplain. Constructed from 1923 through 1926, the nearly 45 ft (13.7 m) tall structure has performed admirably throughout its nine decades of service. In recent years, however, damage from erosion at the toe of the structure and buckling of its concrete facing began to impact the levee's effectiveness, so directors of the Pueblo Conservancy District set a process in motion to repair the levee and protect the city's commercial center.

The renovation, which will ultimately require nearly 10 years to complete, started in 2012, when NorthStar Engineering and Surveying, Inc., was retained to assess the scope of the project, which included engineering solutions and establishing a funding mechanism for the needed repairs. CTL|Thompson, Inc., joined the project in 2013 during the preliminary design phase. The initial phase of rehabilitation work went to bid in the fall of 2014, and construction began in November 2014. An estimated three more phases remain, encompassing 3 to 4 more years.

Inventive Solutions to Resolve Historic Challenges

Since the Pueblo levee project began, the design and construction team has negotiated challenges and complications in several key areas, including engineering the repairs, complying with federal program rules, and navigating the local political landscape.

Going in, the team knew that rehabilitation work would have to comply with the requirements of the Federal Emergency Management Agency (FEMA) National Flood Insurance Program, which set forth certification rules after Hurricane Katrina, as well as the U.S. Army Corps of Engineers (USACE) Levee Safety Program.

The team also knew about an unlikely issue—the levee held the Guinness World Record for the world's largest outdoor mural, created by contributions from thousands of artists over four decades (Fig. 1). The team would need to work hand-in-hand with community groups deeply interested in the final outcome, including historians, city staff, elected officials, artists' groups, and the team of contractors. To successfully address a professional and cultural challenge of this magnitude, thorough and constant communication was key.

The most significant challenges of the Pueblo levee project—and their associated resolutions—are discussed in the following sections.

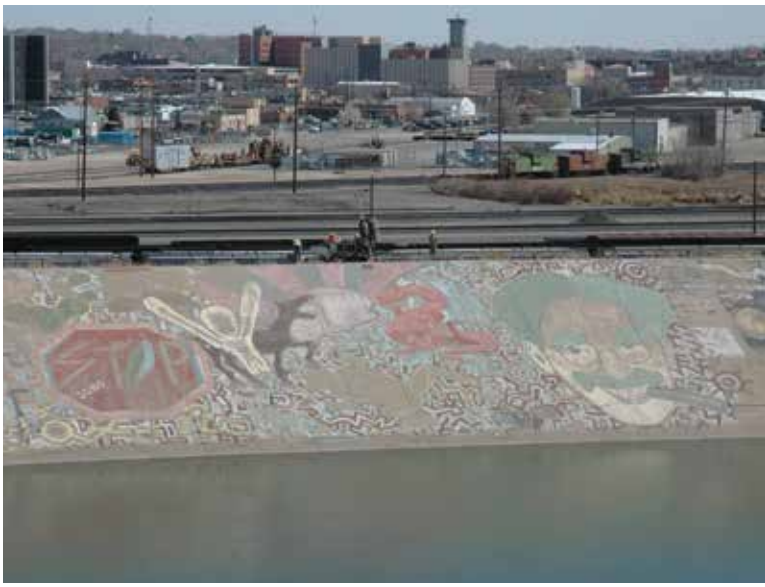

Fig. 1: The river side of the levee in Pueblo, CO, included a large mural produced by multiple artists. The levee was evaluated with the aid of borings taken with a narrow-track drilling rig (center)

Funding for levee improvements

Although the Pueblo Conservancy District levied a tax in the 1920s to pay for the initial construction, the assessment stopped in 1955, when tax levies paid off the bonds that financed that construction. As a result of zoning changes, demolitions, rebuilds, and changes in property ownership over the 90 years since the levee was built, it was extremely difficult to determine an equitable format for restoring maintenance fund assessments.

Fortunately, the district board and the design team were able to demonstrate to the county residents and other government entities that everyone in the county has and will benefit, at least indirectly, from the existence of the levee. In the end, the conservancy district enacted a three-tiered assessment approach, changing the boundaries from the floodplain itself to all of Pueblo County. The new funding mechanism provides for a maintenance fund assessment, which will continue to fund the current renovations.

Steep slopes, limited access, and limited information

The first great engineering challenge was the evaluation of the existing concrete facing of the levee, which was close to 100 years old. With the facing's thickness varying between 6 and 12 in. (150 and 300 mm), cracking, buckling, and spalling had occurred. The team also found numerous voids of varying magnitude in the subgrade beneath the existing concrete facing panels.

The levee faces are so steep that the team couldn't walk or drive typical equipment up them to access the levee's narrow crest (which varied from only 4 to 8 ft [1.2 to 2.4 m] in width). A river on one side and, along most of the levee's length, a major railroad switching yard on the other side limited access to the work area. Bridges for four major roadways—including Interstate 25—created additional conflicts, as did a residential neighborhood with homes built up to the toe of the levee. Finally, river flows restricted work activities to November through March.

Initial plans for conducting soil surveys called for lowering a mini-drilling rig from the bridges crossing the levee. However, the design team feared that the light-duty machine might not be capable of reaching adequate depths. The adjacent switching yard operations required coordination with the railroad to drill at the land side embankment toe, and they presented significant potential safety hazards for the drilling crew. Any drilling at the toe of the levee outside the rail yard was restricted to public streets or alleys.

Fortunately, the rehabilitation team was able to procure a drilling rig that was capable of drilling to adequate depth, could be driven up the levee face, and had only a 4 ft (1.2 m) wide track. Because it could access and move along the narrow crest of the levee without the need for a crane, the cost of operating the narrow-track rig was almost one-third of that estimated for the light-duty, crane-set rig.

Although the narrow drilling rig solved the subsurface investigation issue, the narrow width at the crest still created a major construction issue. Fortunately, through hydraulic evaluation, NorthStar found that the levee could be reduced in height yet still provide the required level of flood protection. Reducing the levee's height allowed the width of the crest to be increased to 20 ft (6 m), helping to facilitate construction and lower rehabilitation costs.

Finally, the team found that maps, charts, and other potentially helpful documents were in short supply during the first phase of the project. Because there was essentially no history on the levee's construction, the team recommended a test program for construction of the first 2000 ft (610 m) of the levee's length. The test was designed to expose major soil conditions, confirming the data from the borings and providing insight into how the levee was built.

A challenge for restoring levee toe and concrete facing

The team found that the toe of the levee at the upstream end was actually 8 ft (2.4 m) below the active river bottom. This finding was a surprise, and it created a challenge for restoring the toe and its concrete facing. The challenge was met by installing a sheet piling cofferdam from the river side during the first phase of the project, allowing dewatering of the toe, and creating a dry working environment for full-height restoration of the concrete facing (Fig. 2).

Compaction grouting and soil anchors were studied as alternatives to complete concrete replacement but were rejected for the first phase of the project. Due to unknown subgrade conditions at the toe of the levee—which was about 40 ft (12.2 m) below and 40 ft beyond the point where any test holes could be drilled—the team decided the cost of grouting or anchors could not be reasonably estimated. The team will re-evaluate this decision for future project phases.

The new facing was anchored to the existing facing at the base. The concrete mixture for the facing was Class P per Sections 601.02 and 601.03 of the Colorado Department of Transportation (CDOT) Construction Manual, with proportioning per Section 601 using a maximum of 20% fly ash per Section 412.04 of the CDOT manual. Type II cement was required, with a water-cement ratio (w/c) not to exceed 0.50 and air entrainment of 5 to 7%. The minimum 28-day compressive strength was specified as 4200 psi (29 MPa).

Concrete was placed around existing sheet piling at the toe where it existed. Where sheet piling did not exist, the toe was rekeyed into the existing substrata, resulting in a thickened edge. A perimeter drain was installed behind the toe, leading the soil embankment in some areas to appear nearly vertical.

Historical and artistic significance

Although the original levee is not on the historic registry, the means and methods used to build it were considered "of the time," signaling a need for the state historic preservation officer to provide approvals. In December 2014, SWCA

Fig. 2: A hydrologic study showed that the Pueblo levee could be lowered. The original height and narrow top of the levee can be seen in the background (upstream). The toe of the downstream portion of the levee was found to be below the river level, so sheet piling was used to provide access for construction of the new concrete facing

Fig. 3: The lowered levee provided a wide access way for concrete delivery. Concrete trucks were routed up a temporary access embankment and delivered concrete to a conveyor that placed the zero-slump concrete mixture ahead of the canal paver

Environmental Consultants of Denver performed a cultural resources inventory, enabling the Phase 1 contractor to proceed. The goal of the inventory was to "serve to resolve adverse effects ... of the proposed rehabilitation of the Arkansas River Levee through Pueblo, Colorado."

To receive input and satisfy requirements, NorthStar is notifying the USACE—which had alerted the team to the additional approval—and other agencies of progress being made on the project. Provided those requirements are met, approval will be granted when construction is finished.

Plans for lowering the height of the levee and replacing the existing concrete facing also created concerns within the local artistic community, as the water-facing side of the structure included a large mural produced by multiple artists. Unfortunately, the rehabilitation work would destroy the mural.

Recognizing the importance of the mural to its creators as well as the community at large, the design team has held ongoing meetings with the artist community to understand its concerns and seek reasonable solutions. To preserve the historic record, the district had high-resolution photos taken of each mural along the levee. Although the original work will be destroyed, the team created a way for artists to safely access the water side and create new murals as the project progresses. A groundswell of interest has emerged in redesigning a long-term solution that will beautify the community and provide artists a showcase for their work.

A Coordinated Team Paves the Way to a Smooth Project

Levees are not certified until reconstruction is complete, but thanks to a well-coordinated team, the work on the levee is well underway (Fig. 3).

While the design and construction team still has years of work ahead, we have found that our initial success can be attributed to more than just sound engineering expertise. By communicating early and often and identifying areas of collaboration and cooperation, we have overcome great obstacles and will rely on the team approach to ensure our future success.

Selected for reader interest by the editors.

Project Design Principals

CTL|Thompson, Inc., is a full-service geotechnical, structural, environmental, and materials engineering firm established in 1971. The firm currently has five offices in Colorado and one in Wyoming. For more information, visit **www.ctlt.com**.

NorthStar Engineering and Surveying, Inc., is a privately owned, full-service civil engineering and surveying firm located in Pueblo, CO. NorthStar and its predecessor firms have been serving Southern Colorado continually from its downtown Pueblo office since 1939. For more information, visit **www.northstar-co.com**.

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