

HIGH-TECH PROCESSES TO PRODUCE VIRTUAL MODEL OF POWERHOUSE

The first step involved in the complex task of renovating the Byllesby Dam powerhouse is determining how the building was originally constructed.

But doing that isn't easy when it's clear those who built the powerhouse more than 100 years ago did not strictly follow the original architectural drawings and failed to record their many deviations from those plans.

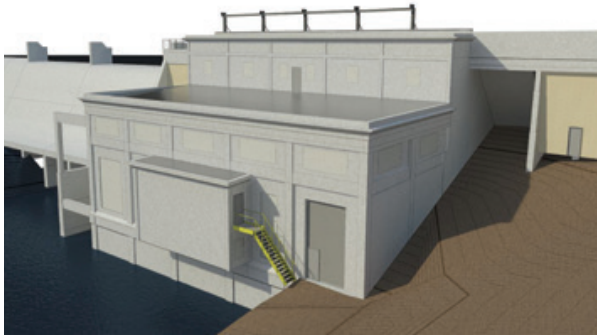
That's the challenge facing the Ayres Associates team hired by Dakota County, Minnesota, to rehabilitate the structure into a modern-day producer of electricity, while recognizing its early 20th century aesthetic glory.

Last December Jason Ingram, Ayres' manager of land survey, sent a two-person survey crew to the Byllesby Dam site armed with the latest in high-density, or HD, laser technology. The surveyors spent two days at the site taking a set of 62 high-density laser scans of the entire complex – the dam, its adjoining floodgates, and the powerhouse.

Each of those scans creates a 3-D dataset of that part of the dam site, Ingram explained. "The scanner measures features at a rate of up to 1 million points per second, mapping in such detail that it can look like a photograph when viewing the point cloud dataset," he said.

Each of these 62 sets of data, called a "point cloud," provides precise measurements detailing key information, such as materials used, the thickness of walls, where pipes enter and exit walls, flatness of floors, and much more.

Through a process called "registering," surveyors will analyze each point cloud and convert the data



into one "point cloud dataset." This registration process "is like putting a puzzle together, piecing each of the 62 scans together with survey-grade accuracies," Ingram said.

Another advantage to scanning that was recognized on this project was the equipment's ability to pick up data on everything it can see and measure. For example, the scanning picked up the existing spillway, which is being rehabilitated, along with areas that had concrete removed along its surface. From the point cloud, cross-sections were cut and an existing surface model was generated to aid engineering staff in determining a proposed finished profile of the surface for construction. Although this was not the targeted use of the point cloud, the technology enabled all data to be collected and saved for future benefits to design staff without the need for more costly site visits.

Once that puzzle is completed, the point cloud dataset will be sent to Ayres' BIM Specialist Bryant Christenson. BIM stands for Building Information Modeling, a process

by which Christenson will use Revit computer software to convert the "point cloud dataset" into a 3-D computer model of the entire Byllesby Dam site, including every room within the powerhouse.

"This will give a very good representation of what's there," he said. "It will indicate all the materials that are there and their condition."

Ingram explained that these 3-D computer models will enable Ayres architects to, in a 3-D virtual environment, remove existing equipment and add proposed new equipment to the powerhouse while identifying any potential conflicts with the building's existing infrastructure.

Further down the road, Christenson said, Ayres also will be able to use the 3-D computer models to create pictures of their redesign proposals that can be shown at public meetings related to the powerhouse project. When a final design decision is made, those models will be used in creating the project's construction documents.

— Bob Brown



Studying Streambank Stabilization

Research team studies options, makes science-backed recommendations

By Tawny Quast

When it comes to stabilizing a stream or river bank, two basic schools of thought exist: using a "hard" engineered approach of rocks, concrete blocks, and other man-made materials to protect the bank; or using the "soft" environmentally sensitive approach of vegetation and natural material. However, the answer to what's the best way to protect a bank isn't so basic, with many opinions about what techniques work best under what

circumstances. A combination of these two approaches, often called "biotechnical streambank protection," may in many cases offer an optimal solution.

Essentially, keeping a highway safe from an unstable bank is a serious matter, with people's lives at risk if a structure such as a bridge were to fail. And to an engineer responsible for designing streambank protection measures, mere opinions of what works aren't good enough.

"You need to emphasize good solid engineering when it comes to streambank stabilization," explained Pete Lagasse, senior hydraulic engineer at Ayres Associates. "The problem with just using vegetation (to protect a bank) has been that there was little quantitative information out there to give an engineer the confidence to stand behind that design."

STUDY GOALS OUTLINED

Which is exactly why the National Cooperative Highway Research Program (NCHRP) embarked on a study aimed at backing the design and installation of streambank protection measures with solid, quantifiable research. NCHRP is a forum for coordinated and collaborative research administered by the National Academy of Science's Transportation Research Board in cooperation with the American Association of State Highway and Transportation Officials (AASHTO) and the Federal Highway

ABOUT THE TRANSPORTATION RESEARCH BOARD

The Transportation Research Board (TRB) is one of six major divisions of the National Research Council. The mission of the TRB is to provide leadership in transportation innovation and progress through research and information exchange. The Board's activities annually engage about 7,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia. The program is supported by state transportation departments and federal agencies. For more information, see www.TRB.org.

Credit: www.national-academies.org

Administration. The NCHRP provides practical, ready-to-implement solutions to pressing problems facing the transportation industry.

In June 2013 NCHRP selected a team led by Ayres Associates to conduct an evaluation and assessment of environmentally sensitive streambank protection measures. The objective of the research project was to evaluate and assess existing guidelines for the design, installation, monitoring, and maintenance of environmentally sensitive bank stabilization and protection. Another goal of the project was to provide practical, quantitative design guidelines that engineers could use with confidence.

Lagasse served as principal investigator, and Paul Clopper, director of applied technology at Ayres, served as a co-principal investigator for the project, which wrapped up in November 2015. The NCHRP research report is in the process of being published as NCHRP Report 822.

Doug Shields, a hydraulic engineering consultant at Shields Engineering LLC and a member of the Ayres NCHRP research team for this project, agreed with Lagasse that the lack of data behind vegetative



bank protection techniques was problematic for engineers.

"Most people are willing to affirm the environmental value of a river or stream, but when you're building a highway, you need to make sure the bank protection will hold up," Shields said. "The problem was that there were no clear standards to do this."

METHODS PUT IN PLACE

To start the project, the team reviewed a 2005 NCHRP study that focused primarily on using vegetation techniques for streambank stabilization. The study identified 44 different environmentally sensitive bank protection measures but did not test the techniques in real-world scenarios. The Ayres NCHRP study aimed to compare combinations of engineered and vegetative bank protection measures in a laboratory set up to mimic real stream conditions, Lagasse explained.

In essence, the Federal Highway Administration recommends using a combination of engineered and vegetative bank protection methods when protecting roads, bridges, and other infrastructure.

Pete Lagasse, top, and Paul Clopper, bottom, monitor willows growing at the Colorado State University greenhouse.



Willows were grown in the Colorado State University to use as part of the research project.

"Some resource agencies such as state departments of natural resources tend to discourage, and in some cases actually prohibit, the use of rock for streambank protection; they push for using some kind of vegetation," Lagasse said. "But we feel that using vegetation and hard material together is best."

David Reynaud, senior program officer with the NCHRP, agreed that more and more entities are pushing for environmentally sensitive techniques.

"There's a movement in the environmental area to use natural materials rather than stone or other man-made materials," Reynaud said.

Using vegetation provides environmental and aesthetic benefits, improves conditions for fisheries and wildlife, and helps improve water quality. However, vegetation also has its limitations. Plants can fail to grow or can die in drought conditions, they can get eaten by wildlife or livestock, and they may require significant maintenance, to name a few potential problems. Therefore, the study recommends that "vegetation alone should not be seriously considered as a countermeasure against severe bank erosion where a highway facility is at risk" but should

be used in combination with other "hard" engineering approaches.

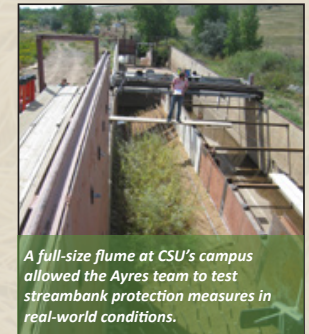
TIME FOR TESTING

To conduct their study, the NCHRP team devised a test in cooperation with the hydraulics laboratory at Colorado State University (CSU) in Fort Collins, Colorado. First, the team selected two bank protection treatments from the original 2005 NCHRP report to test with the CSU flume, which is a full-size model of an open channel that simulates real river flow conditions. Using a flume to test bank protection treatments with a live vegetative component had never been done before, Lagasse said.

What made the test even more revolutionary was that the team grew willows to maturity at real-scale in a climate-controlled greenhouse at CSU and then transferred them to the flume.

"We were able to take the biotechnical treatments to the big outdoor flume and subject them to water discharges to simulate various levels of river flow, and then see how the vegetation reacted to the flow," Lagasse explained.

The team conducted two tests. The first test, a biotechnical



A full-size flume at CSU's campus allowed the Ayres team to test streambank protection measures in real-world conditions.

approach, used a rock toe (base of the bank) with locally harvested willows. The second treatment tested a combination of vegetation with a natural fabric material configured in soil lifts with willows inserted between the lifts, a technique commonly called vegetated mechanically stabilized earth (VMSE).

To transport the willows from the greenhouse, the willow trays were put on rollers and pulled out with tractors. A crane put the trays into place in the flume. For each test, water ran for four hours through the flume, and velocity was measured at various points. Following each test, changes or damage to the treatment were examined and documented for analysis.

"This type of test had not been done before. No one had this idea or this type of facility; we were truly using real-world conditions," Lagasse said. "This was a major quantum leap forward."

RESULTS REVEALED

In the end, the tests showed that of the two treatments tested in the laboratory, one (live siltation and live staking with a stone toe) met or exceeded all performance expectations. The second treatment

NCHRP PROJECT HISTORY

Ayres led projects for the National Cooperative Highway Research Program over the last 20 years totaling \$4,266,000. These projects are:

Instrumentation for Measuring Scour at Bridge Piers and Abutments (1997)

Portable Scour Monitoring Equipment (2004)

Handbook for Predicting Meander Migration (2004)

Riprap Design Criteria, Recommended Specifications, and Quality Control (2006)

Countermeasures to Protect Bridge Piers from Scour (2007)

Effects of Debris on Bridge Pier Scour (2010)

Reference Guide for Applying Risk-Based Approaches for Bridge Scour Prediction (2013)

Evaluation and Assessment of Environmentally Sensitive Streambank Protection Measures (2015)

Underwater Installation of Filter Systems for Scour and Other Erosion Control Countermeasures (Under way)

(vegetated mechanically stabilized earth without a hard toe) exhibited vulnerabilities to damage and soil loss under the same flow conditions.

In addition to performing the laboratory tests, the research project also included visiting sites throughout the country to observe the long-term performance of various biotechnical measures in the field. Teams were sent out to gather design and performance information and compare those results to what was found in the laboratory. From the field visits, the team developed a comprehensive compendium database that will be published with the final report, providing information on practical methods gained from field experience in a searchable database format.

At NCHRP Reynaud applauds the study for giving verifiable back-up to the use of vegetation such as willows as a natural streambank protection technique.

"With the willow, this is actually something that's growing and substantial. Now we can demonstrate that this is a better way to go," he said. "We're using something that's naturally occurring but in a way that's verified and tested in an engineering manner."

Beyond the research advancing the state of engineering practice, Reynaud praises the project team, led by Lagasse and Clopper, for its top-notch work.

"Pete puts together the best project teams that we've ever worked with. They are the cream of the crop," he said. "Ayres always delivers on time, and Pete is legendary."

Ultimately, Shields says the research project provided a

For a time lapse video showing the willows growing at the Colorado State University greenhouse, please visit <https://www.youtube.com/watch?v=JAV7GSQvgcc>



thorough study that addressed real-world problems.

"It added a nice chunk of engineering to the base of experience that practitioners can use. This gives engineers more confidence and an ability to control risk in a cost-effective fashion," he says.

Ultimately, Lagasse says that the biggest benefit of the research is to provide a guidance resource for engineers.

"It gives tricks of the trade, lessons learned, and quantitative information on how to measure whether vegetative components are performing as designed," he said. "It provides step-by-step guidelines on how to design biotechnical protection methods."

Lagasse said while this research only tested two methods in the laboratory, he sees a potential for testing many more methods, such as vegetative riprap, an approach favored by many transportation agencies, in a similar way, as funding is available.

"For the first time we have an approach to do this," he said. "The Ayres/CSU team proved it could be done, and we developed a protocol to do it." ■

Project sets out to *protect* streambanks

The City of Fort Collins, Colorado, has been busy practicing some of the stream restoration techniques that were tested as part of the National Cooperative Highway Research Program's (NCHRP) environmentally sensitive streambank protection research project – namely using a combination of vegetation and rock toe to protect streambanks.

The City's Stream Restoration and Habitat Enhancement project involves stabilizing stream channels, restoring and creating new native in-stream and riparian habitat to attract and support fish and wildlife, and promoting best management practices to improve water quality in streams throughout Fort Collins.

Sue Paquette, project manager for Fort Collins Utilities, says this project benefits the community by making the floodplain more stable, mitigating erosion, stabilizing channel banks, and enhancing water quality.

"This helps make the area more ecologically diverse and hopefully brings back native species and fauna to the riparian corridor," she said.

Fort Collins Utilities is working with Ayres Associates as part of a multidisciplinary group of experts on the streambank protection project. Dusty Robinson, civil engineer in Ayres Associates' Fort Collins office, is heading up the project for Ayres, which is part of a five-year contract with the City. In all, about 40 sections of streams in Fort Collins will be evaluated, with



the highest priority sections already completed or under way.

Protecting streambanks has become more common in the last 10 years, Robinson said.

"For a long time, rivers have been neglected and often were a dumping ground," he said.

Development affects runoff, often putting more water into streams, and more water causes banks to erode and can destroy wetlands.

More erosion in rural areas isn't as catastrophic, but when banks erode in urban settings, stream destabilization becomes more critical and threatens infrastructure, Robinson explained. With Fossil Creek, the first reach the project team worked to protect, the stream cut into the bank and created a 15-foot vertical wall.

"A light post and softball field scoreboard were being threatened, and a water quality pond was close to being breached," he said. "As erosion starts to impact infrastructure, it's a big deal."

Essentially, the project has two components: bank stabilization and rehabilitating or creating wildlife habitat, Robinson explained. The bank stabilization component so far has involved using stabilization (such as rocks) along the toe of the streambank. It also includes developing healthy wetlands along



the banks by using willows to provide stabilization through those areas. This method is similar to that tested as part of the NCHRP research project.

Additionally, the project team is working to replace the banks with vegetation that will improve habitat for wildlife, a method that looks at injecting diversity and complexity into the ecosystem.

"We're giving the river system a jump start," Robinson said. "We stabilize it, get the right structure in place, and then allow natural things to happen."

This kind of work requires coordination between many disciplines. Ayres is responsible for the hydraulic and hydrology work, grading, bank stabilization, channel design, and geomorphology. Aquatic biologists look at species and how materials interact with habitats. Ecologists identify plants and soils and prepare permits. Fort Collins Utilities is managing the project under an Alternate Project Delivery System (APDS), in which all team members, including the construction contractor, work together from start to finish.

"You need good communication and close coordination with your contractor for a project like this," Robinson said. "The APDS system provides for this because it brings all the people together."

Left: Vegetated mechanically stabilized earth (VMSE) bank protection in Fossil Creek in Fort Collins, Colorado, immediately after construction. Right: Upper portion of Fossil Creek channel after one growing season.

Paquette said she's enjoyed being able to work outside with a great group of people that share the same goals: to make the stream channel more natural, stable, and better prepared to handle various degrees of flows and sediment loads.

The APDS system worked well with this project, providing a team atmosphere where everyone was able to contribute ideas and using everyone's strengths and experience.

"Dusty (Robinson) has a lot of great ideas and experience and is willing to share and work with the team to get the work done," Paquette said.

Personally, Robinson has found this project a perfect complement to his love of rivers. He is an avid rafter and kayaker and sees firsthand the value of the waterway.

"When I see a river neglected and treated as an afterthought, it's a bummer because you know its potential," he said.

– Tawny Quast