An Innovative Tainter Gate Dewatering System That Could Save Your Lake

M. Leslie Boyd, P.E., Senior Lead Engineer, Freese and Nichols, Inc.
Doug Witkowski, P.E., Principal Engineer, Lower Colorado River Authority
Layne Bukhair, P.E., Design Engineer, Freese and Nichols, Inc.
Victor Vasquez, P.E., Project Manager, Freese and Nichols, Inc.

I. ABSTRACT

In 2014, the Lower Colorado River Authority (LCRA) completed what is believed to be the only tainter gate dewatering system capable of deployment in an emergency situation involving a failed tainter gate. The tainter gate failure at Folsom Dam awakened numerous dam owners to the possibility of a failed gate resulting in loss of a reservoir’s valuable water. Thus, when LCRA embarked on developing a gate dewatering system to accomplish the gate modernization repairs on thirty gates at Buchanan Dam, they requested that the system also be deployable in an emergency involving flowing water through a failed gate. LCRA evaluated the quantity of water which could be lost by a gate failure draining Lake Buchanan down to its concrete crest and deemed it unacceptable. Therefore, having emergency deployment capability became a priority of the dewatering system development. When the initial concept was developed it was subjected to an extensive hydraulic model evaluation period to prove its capability of deployment in both normal and emergency situations. After this model study proved the viability of the system, LCRA commenced designing, fabricating, and installing a complete dewatering system for all thirty gates. The system is now complete and has the capability to dewater four gates at a time to facilitate the timely modernization improvements to the thirty gates. This paper will present the unique aspects of this dewatering system and explain in detail how LCRA performed the majority of all fabrication and installation with their own staff.

II. BACKGROUND

Buchanan Dam was constructed in 1938 and did not include any type of dewatering system for its tainter gates. This was not uncommon for this era of dam construction. However, not having a tainter gate dewatering system makes it difficult to perform gate repairs safely. It can also discourage cycling gates when water supplies are critical and a fear exists of opening a gate and not being able to get the gate closed. Thus, when LCRA determined that their tainter gates needed gate repairs/structural strengthening to meet current dam safety criteria, they first had to develop a dewatering system. LCRA contracted Freese and Nichols, Inc. (FNI) to study dewatering alternatives for Buchanan Dam and to develop a dewatering system capable of deployment in both normal and emergency situations. This paper presents the journey from concept development to final installation of the dewatering system at two of the Buchanan Dam spillways.
III. CONCEPT DEVELOPMENT

A. Background of a Typical Stoplog System

A typical tainter gate dewatering system is installed in a balanced condition, i.e., the dewatering panels (stoplogs) are lowered into the reservoir while the tainter gate is closed and there are no unbalanced pressures acting on the stoplogs. The typical system consists of panels which are handled by a lifting beam and stacked vertically in a slot. This typically works well in still water conditions. A typical system is shown below in Photo 1. The typical problem encountered with the dewatering system is associated with the lifting beam. The lifting beam is submerged for a large part of its travel and is not visible when it is disconnected from a stoplog beneath the reservoir surface. Sometimes the disconnection operation only releases one side of the stoplog and subsequent lifting results in either damage to the lifting beam or wedging of the stoplog in the slot. Thus, some dam owners require the presence of divers during all stoplog operations.

The stoplogs see significant forces only after they are completely stacked and the tainter gate is opened. At this point the stoplogs see the full horizontal force exerted by the reservoir. The stoplogs remain in place after the tainter gate is closed. Once closed, the stoplogs can be removed in a balanced condition and no significant frictional resistance is encountered.

![Photo 1-Typical Stoplog System](image)

B. Emergency Stoplogs

Friction is seldom a significant issue in a typical stoplog deployment operation. However, when a stoplog system is to be installed in front of an open gate, friction becomes paramount. The reservoir is no longer balanced on each side of the stoplogs and produces high frictional resistance to the lowering of the stoplogs. In addition, the flowing water renders the typical lifting beam essentially useless since it cannot be maneuvered and actuated properly in flowing water conditions.
Thus, the primary parts of the conceptual design of the emergency dewatering system considered the use of wheels to reduce friction during emergency deployment and adequate weight to push through flowing water. Another important aspect was to eliminate the shortcomings of a traditional lifting beam and allow deployment in both still water and flowing water. The initial concept is illustrated in Figure 1. The stoplogs hinge together similar to a garage door and travel down a set of steel guide tracks to access a suitable sealing surface on the existing concrete crest. The logs are sealed steel tubes. This conceptual design was recognized as needing verification testing for use in emergency situations such as a failed or stuck gate. Freese and Nichols recommended and LCRA agreed to a physical model study of the proposed concept. The testing and results are presented below.

Figure 1-Initial Concept
IV. CONCEPT VERIFICATION

A. The Model

FNI developed preliminary concept drawings to a level of detail where Utah Water Research Laboratory (UWRL) could construct the hydraulic model components necessary for the study. The UWRL model team was led by Mike Johnson, P.E. The following is a very brief summary of the extensive efforts provided by UWRL on this investigation and is not intended to be a complete or all-inclusive presentation. UWRL selected a model scale of 1:16.5 and determined that a Froude model was appropriate for the items needing study. UWRL constructed a gate and spillway model in the flume of their research facility in Logan, Utah. Photo 2 is a photograph of the spillway model and flume. The key issues presented for study were:

- Could the system be deployed in flowing water
- What effect would the tracks mounted on the vertical pier face have on discharge capacity
- What pier nose modification provided acceptable hydraulic flow
- What, if any, hydraulic phenomenon or forces were occurring on the stop logs
- What loads would be imparted to the lifting mechanisms (cables)

UWRL had the stop logs machined from aluminum and duplicated the hinging and wheel system very thoroughly. Weights were also controlled to the proper model ratio by machining out the cavity within each log until the appropriate weight was obtained. The rubber seals were simulated using thin rubber strips. Load cells were placed on each lifting cable to measure the loads. The entire system was monitored with computers to provide real time output which was stored for future reference.

Photo 2-Spillway Model
B. Results

The UWRL model study was a resounding success and indicated the proposed system was viable for Buchanan Dam’s small gates. A complete Hydraulic Model Study Report was prepared by UWRL and affords a much more detailed look at the system. However for the purpose of this paper, the significant findings were:

- The curved guide track system is viable in both still and flowing water.
- The reduction in flow capacity caused by the projecting tracks is minimal.
- There is no noted hydraulic phenomenon causing adverse conditions. A small jump was noted occurring on the downstream apron for just a few moments before the bottom log fully seated.
- The maximum load on each lifting cable was approximately 37,000 pounds and this corresponds essentially with the dead weight of the stop log system.

V. DESIGN

A. Stoplogs

Once the verification testing was successfully completed and indicated the viability of the concept, LCRA authorized final design of the dewatering system. The logs were designed from Hollow Structural Sections (HSS) tubing. The tubes are 39 inches tall and 16 inches wide. Each log is 32'-8” long and weighs approximately 12,000 pounds. The tubes were selected to allow adding water ballast to sealed compartments in the event additional weight was needed to sink the stoplogs in an emergency. In normal conditions the logs would be reduced in weight due to buoyant forces acting outside the sealed compartments. The HSS tubes also offer a clean profile which is less susceptible to corrosion than a system of built-up structural beams and plates. A complete stack of six logs is required to dewater one tainter gate. Five of the six logs are identical and can be stacked in any sequence once the bottom log is in place. Only the bottom log is special since it requires bottom seals to seat on the concrete crest. The bottom logs are easily identified by their lack of a bottom flap seal.

The stoplogs have two steel wheels on each end of the logs with non-corrosive, non-metallic bushings turning on hard chromed 4140 steel axles. This should preclude the occurrence of rusted bearings which would increase the friction and affect proper operation of the system. The axles were utilized as part of the lifting system by placing a permanent shackle around each upper axle during fabrication. Each shackle is capable of lifting the entire stack of six logs. The shackle drops out of the way into a cavity in the log when not in use and a small retrieval loop is readily accessible. Thus, there is no rigging necessary to lift the logs. The pin in the crane hook simply passes through the shackle. Also, each log acts as a lifting beam. There is no separate lifting beam in this system.

The key feature of this system which makes it work in emergency situations is the stacking of the logs to form a massive assemblage which is capable of pushing its way through flowing water. The stacking is accomplished by a repetition of “pinning” and “dogging” logs together as follows:

- Place the bottom log in the bay to be dewatered and “dog” it atop the piers
- Release the crane to retrieve the next log
- Place the log atop the bottom log and insert the pins into the hinges
- Lift the assemblage and remove the dogging pins
- Lower the assemblage so the top log can now be dogged atop the piers
- Repeat until six logs are pinned together in one bay
- Lower the assemblage until the bottom log is seated on the concrete crest
Stacking the assemblage creates a massive panel capable of cutting through the flowing water without ever having any log overtopped or the lifting mechanism submerged. This is critical to a successful emergency dewatering system.

B. Deployment System

The deployment system designed for this dewatering system is a series of structural steel HSS bents mounted on the top of all concrete piers at 39-foot spacing. The bents have a vertical leg on the downstream end of each pier, a vertical leg on each upstream end, and a horizontal tube connecting the two. This forms a large upside-down "U" bent which then supports a monorail beam extending the entire length of the spillway. One spillway is approximately 500 feet long and the other is approximately 600 feet long. The HSS bent system is shown in Photo 10 of Section VI. There are two sets of six logs on each spillway. The logs are stored one per bay on the guide tracks. They are dogged atop each pier when in storage. This leaves at least two bays empty to facilitate log management. The log guide tracks are all on the same centerline which allows the monorail crane to service each bay. No lateral movements are required for installing or storing the stoplogs.

The extensive length of the bent system required a design that could accommodate nearly 4 inches of longitudinal length change due to temperature variations. The expansion movements were accommodated by a series of approximately ten sliding joints working on low-friction surfaces. The stability for the system was provided by rigid bays integrated between select expansion bays. To accommodate the monorail wheels traversing the changing joint widths, “chevron cuts” were made on the lower flange of all monorail beams. Chevron cuts simply allow the wheels to traverse a joint without dropping due to the angularity of the chevron cut.

C. Hoist

The development of the hoist for this project was selected to be a very long hoist, approximately 44 feet, which had a truck near each end of the hoist to place the heavy lifting load close to the support bents on each pier. The hoist should never travel with more than one log in order to keep the monorail beam of reasonable weight. All heavy lifts of stacked logs occur only when the trucks are at the piers. The hoist was designed to be a two-hook traveling monorail hoist capable of lifting a stack of six stoplogs filled with water ballast. The maximum load required was approximately 100,000 pounds. Thus, each hook had to be rated for 50,000 pounds (25 tons). The biggest challenge to the design of the hoist was the lack of available space within the bent system constructed on top of the existing concrete piers. The monorail hoist had to fit between the spillway gate hoists and the upstream bent leg. This available space was approximately 46 inches. In addition, the minimum hook drop below the monorail beam was only 63 inches. This limited the number of hoist vendors willing to approach the design required by the tight clearances.

The monorail hoist constructed for the project is a two-hook, under-running 50-ton crane. The hoist was custom built in Texas by a specialty fabricator to meet the project specifications/limitations. The hoist can operate at multiple speeds depending on the application, and has limit switches to prevent over travel. The hoist was load tested to 125% of rated capacity and is shown in Photo 7.
VI. FABRICATION AND INSTALLATION

LCRA maintains a fleet of over 1,600 coal rail cars at their Smithville, Texas, maintenance facility. The facility has steel fabrication capabilities beyond those required for maintaining the rail fleet. This facility has produced crest gates, floating bulkheads, head gates, needle beam cofferdams, and miscellaneous steel work for numerous projects through the years. LCRA fabricated the dewatering system to streamline the design-build process and to accomplish the fabrication with a high degree of quality control.

In addition to providing fabrication of the dewatering system, LCRA used their Buchanan construction crews to install the dewatering system. This provided a unique aspect to this project in that LCRA served a dual role as client and construction contractor. The collaboration between the LCRA construction team and fabrication team helped deliver the product to tolerances greater than industry standards.

A. Concrete Modifications

The existing pier noses and gate hoist walkway required modifications to facilitate the installation of the system. The pier noses were reshaped to provide an adequate sealing surface for the stoplog side seals and an acceptably efficient hydraulic shape. The piers have a blunt nose with an elliptical transition as show in Photo 3. The existing concrete gate hoist walkway was sawcut and removed to allow for installation of the stoplogs as shown in Photo 4. These concrete modifications were initially performed by contractors under the supervision of LCRA, to develop the procedures. Ultimately, LCRA purchased special cutting equipment and completed the work themselves.

Photo 3- New Concrete Piers
B. Guide Track and Stoplogs

The dewatering system for the 14-gate and 16-gate spillways utilizes stoplogs that descend along a curved steel guide track bolted on the face of each pier. The guide tracks are 4-inch-by-4-inch rails. The lower guides are solid steel bars mounted on 1-1/2 inch-thick plates, the middle rails are 4-inch-by-4-inch solid bar with through bolts for mounting, and the upper guides are HSS with through bolts. The tracks are shown in Photo 5.
The stoplogs were fabricated by LCRA and each stoplog includes lifting shackles, idler pins, counterweights, wheels, and a dogging system for storage and stacking (Photo 6). To dewater a gate, six stoplogs must be stacked together as a unit. Two additional stoplogs are shown stacked in Photo 7 to provide a hoist lift test. The workers stand on the top of the concrete piers to insert all necessary pins and make all lift connections. The dogging system allows the logs to be stored on top of the concrete piers directly beneath the monorail for easy access. Hinged aluminum walkway gratings allow access to the stoplogs and become fall protection handrails when open (Photo 8).
C. Deployment frame

The deployment system was fully fabricated by LCRA. LCRA’s fabrication crew manufactured the deployment system in the shop to make sure all components met required dimensions. Once the correct fit was obtained, LCRA match-marked the components before disassembly. The shop-erected deployment system can be seen in Photo 9. LCRA then sent the deployment system out for painting, after which it was shipped to Buchanan Dam for final installation. LCRA construction crews handled the erection and miscellaneous construction associated with installing the system. Construction included installing all anchor bolts, aligning all components, field welding, and pouring grout pads upon final adjustment. FNI worked with LCRA to monitor the progress and answer construction questions. The erected deployment frames can be seen in Photo 10.
VII. CONCLUSION

LCRA has completed a dewatering system for Buchanan Dam that can isolate up to four tainter gates at a time and significantly reduce the time required for repairing their thirty spillway gates and bringing them up to current dam safety standards. The dewatering system is also capable of being deployed in an emergency situation such as a failed or stuck open gate. This feature would save Lake Buchanan from losing millions of gallons of precious water. It is believed to be unique as the only emergency tainter gate dewatering system capable of deployment in flowing water at this time.
VIII. REFERENCES

IX. AUTHOR BIOGRAPHIES

M. Leslie Boyd, P.E.
Senior Lead Engineer
Freese and Nichols, Inc.
10431 Morado Circle, Suite 300
Austin, Texas 78759
mlb@freese.com

Mr. Boyd is a senior engineer and Associate at Freese and Nichols, Inc. in Austin, Texas. He has been with Freese and Nichols almost 35 years. Mr. Boyd served as a lead engineer and resident construction manager for the LCRA Highland Lakes Dam Modernization. He earned his Bachelor of Science degree in Civil Engineering from the University of Texas at Arlington and his Master of Science in Civil Engineering from Vanderbilt University. His primary focus for the last 25 years has been on dams. This includes design, post-tensioned anchors, construction, dewatering, and rehabilitation of dams.

Doug Witkowski, P.E.
Principal Engineer
Lower Colorado River Authority
LCRA- P.O. Box 220
Austin, TX 78767
doug.witkowski@lcra.org

Mr. Witkowski is a principal mechanical engineer with the Lower Colorado River Authority (LCRA) in Austin, Texas. He has been with LCRA for thirty three years and has served in progressive levels of engineering at their coal and gas fired generation plants. For the last fourteen years he has served as lead engineer in all of their efforts related to head gate, flood gate and hydro turbine overhauls. He earned his Bachelor of Science in Mechanical Engineering from the University of Texas at Austin.

Layne Bukhair, P.E.
Design Engineer
Freese and Nichols, Inc.
10431 Morado Circle, Suite 300
Austin, Texas 78759
llb@freese.com

Mr. Bukhair is a design engineer at Freese and Nichols, Inc. in Austin, Texas. He has been with Freese and Nichols for 5 years. Mr. Bukhair has served as design engineer and assistant project manager for a variety of projects with the LCRA. He earned his Bachelor of Science degree in Civil Engineering from Texas A&M University. His primary focus has been dams and hydraulic structures.

Victor Vasquez, P.E.
Project Manager
Freese and Nichols, Inc.
10431 Morado Circle, Suite 300
Austin, Texas 78759
vmv@freese.com

Mr. Vasquez is a senior engineer and Principal at Freese and Nichols, Inc. in Austin, Texas. He has been with Freese and Nichols for 17 years. Mr. Vasquez has served as design engineer and project manager for a variety of projects with the LCRA. He earned his Bachelor and Master of Science degrees in Civil Engineering from the University of Texas at Austin. His primary focus has been on new design or rehabilitation of dams and hydraulic structures.