Section IV - Problems, Needs, OpportunitieS and Study Objectives

This section introduces the problems, needs, opportunities and objectives that have led to the production of this report.

1. General

The Tennessee Valley Authority completed construction of Chickamauga Lock and Dam in 1940. The U.S. Army Corps of Engineers designed the lock while TVA designed the remainder of the project. Both agencies share jurisdiction for various activities, including navigation, in the Tennessee River Valley. Periodic inspections of the dam and powerhouse are made by TVA personnel. However, both Corps of Engineers and TVA personnel are involved in the periodic inspection of the lock. In addition, the Corps of Engineers, through a January 2000 memorandum of agreement with TVA, is responsible for operation and maintenance costs associated with the existing lock.

2. Problem

a. Structural Problems. The entire Chickamauga project is plagued with “concrete growth” that results from an alkali-aggregate reaction (AAR). This is a chemical reaction in concrete that occurs when the alkali in the cement reacts with certain silicate or carbonate minerals in the aggregate (rock). This reaction forms a gel that absorbs moisture and swells causing the concrete to expand. For this reaction to occur the aggregate must react with the cement and there must be moisture present. If the concrete is free to expand (like in the lock approach walls), the volume of the concrete increases. When the concrete is restrained (like at the bottom of a lock wall monolith), the growth results in increased internal stresses in the concrete. This irreversible expansion is causing internal stresses throughout the lock that cause cracking and movement of concrete monoliths. This movement causes equipment alignment problems to such items as the miter gate operating machinery and floating mooring bitts and structural stability problems to such portions of the lock as the approach wall support piers or lock wall monoliths.

The trend in growth does not appear to be slowing; therefore, major maintenance not normally associated with a typical lock is increasing causing significant expense and lock outages. These maintenance items may range from simple work like patching spalling concrete and replacing access grating to major maintenance like realigning the miter gates, realigning the floating mooring bitt channels and replacement of the mooring bitt. In addition to continuing maintenance to resolve operational problems, preventive/advance maintenance will be required to maintain the structural integrity of the lock walls and gates to safely function as the water barrier. These maintenance items could be additional anchoring of monoliths or slot cutting. Figures 1 through 6 at the end of this section show some of the AAR impacts on the lock.

The cracking within the monoliths not only affects the lock's stability but it also affects its operation. One concern results from the uncontrolled flow of water into and out of the lock chamber. As this flow of water increases as the cracking worsens, one of several things may occur. The flow of water into the chamber through the upstream monoliths may exceed the ability of the discharge culverts making it impossible to empty the chamber. More likely, however, would be the slowing of the locking process as inflow approaches discharge capabilities. Another concern is the uncontrolled flow of water out of the chamber through the downstream monoliths, which may make it impossible to fill the chamber (flow through the lock walls exceeds the filling capabilities).

Currently, flow out of the chamber through the lower land wall monoliths (downstream of the embankment) is such that the water level within the chamber is not maintained without opening a filling valve (adding water) occasionally. To reduce the flow through the land wall, the water level in the chamber is kept about halfway between the tailwater and headwater elevations.

The contact surfaces of several upstream monoliths with the adjacent earth embankment dam provide a critical link in the water barrier. Seepage of water through cracks in these monoliths could result in internal erosion of the embankment along the interface. If undetected and allowed to progress, an erosion failure of the embankment could occur. This is the most serious of all lock-induced failure scenarios since it would result in rapid and complete loss of the reservoir. For this reason seepage is closely monitored.

The cracking of the concrete monoliths is impacting their structural stability and margins of safety. Water entering open cracks increases uplift above those assumed in the original design and reduce the monoliths capability to resist overturning and sliding from the forces of the water retained in the reservoir. Steel anchoring tendons have been added to all monoliths to restore safety margins. The tendons, however, have a finite life. Failure of significant numbers of tendons will reduce the margins to unacceptable levels. Additional post-tensioning or lock closure would be required when margins fall below acceptable levels. Data from instrumentation installed on many tendons will allow assessment of tendon condition.

b. Structural Condition of Chickamauga Spillway and Powerhouse. The spillway and powerhouse are all concrete structures and both are exhibiting the effects of AAR. The spillway segment is a concrete gravity structure with 18 spillway gates separated by 8' wide concrete piers. The piers are topped with an operating deck, which is primarily a work platform for operating the spillway gates. The weir sections are low compact sections with a height of about 40 feet and a base width of about 35 feet. The upstream side is about 20' feet below rock. The rock was excavated from the downstream side. The ends of the weir sections are confined by the powerhouse on the south end and the lock junction block (Block 44) on the north end.

The spillway piers are also founded on rock with a total height of about 100 feet. The spillway piers support the reactions from the 40-foot wide spillway lift gates. They also support the operating deck and the gantry crane. Along the longitudinal axis of the dam, the piers are relatively tall slender structures much like a cantilever slab.

AAR in the spillway weir section would have its most significant effect along the longitudinal axis of the dam. However, the spillway weir sections are highly restrained. The south end is restrained by the massive concrete of the powerhouse. The north end is restrained by the massive junction block of the lock. Additionally, the weir sections are continuously restrained by the underlying rock and by an approximately 25 foot high vertical rock face on the upstream side.

The spillway weir sections are solid concrete with no internal galleries or culverts. This eliminates one of the primary causes for the extensive cracking that exists in the lock walls. Horizontal cracks have developed in the weir sections, which are similar to those in the lock and other TVA projects with concrete growth problems. Highly restrained members also develop significant internal stresses.

The effects of AAR on the spillway sections are being continuously monitored by approximately 200 instruments. These instruments allow engineers to assess the effects of growth on the operability of the spillway gates and on the overall condition and stability of the spillway.

Significant remediation and life extension activities have been completed for the spillway by TVA. Expansion slots have been cut between the spillway section and the powerhouse and four of the weir sections adjacent to the powerhouse have been post-tensioned.

Many options remain for life extension of the spillway weir sections. These include additional post-tensioning and additional slot cutting. Due to the compact configuration of the weir sections, these rehabilitation activities can be repeated many times. These options are also relatively inexpensive. Therefore, it is expected that the life of weir sections could be extended well beyond 50 years.

Many options also remain for the piers and operating deck. These include both slot cutting and post-tensioning. Neither of the activities has been necessary to date. However, these remediation methods may not be effective for a life extension beyond 50 years. Replacement of the piers and operating deck in the future may be necessary. However, the cost for this replacement would not be prohibitive in relation to other options.

The powerhouse section of the dam is a concrete gravity structure. The substructure of the powerhouse is a rectangular box section with formed openings for the intake, scroll case, and draft tube. The 400’ foot long powerhouse section is similar to the weir sections of the spillway. It is embedded in rock excavation and is highly restrained by the rock.

AAR has been causing significant problems with the hydropower units for over 20 years. Problems include throat ring clearance, wicket gate closing, and misalignment of the head cover and distributor ring. The four units have been disassembled and rehabilitated several times by TVA.

The effects of AAR are being monitored by approximately 100 instruments in the concrete. Additionally, the clearance and alignment of the units is being monitored.

Rehabilitation of the units for realignment is inevitable. Post-tensioning of the concrete may also be needed. Slot cutting poses significant problems due to embedded items but may ultimately be necessary. These rehabilitation activities may allow the hydropower units to extend the life of the hydropower units beyond 50 years. However, if it became uneconomical to continue the operation of the units, the powerhouse section could still be maintained as a water barrier for the dam for more than 50 years.

c. Historical AAR Related Problems. While the future is somewhat hard to predict, we can learn from the past. Following is a historical discussion of AAR related problems and activities over that past 60 years.

The Chickamauga project has suffered from the effects of AAR since shortly after completion in 1940. The first inspection of the dam was made in 1943, about 3 ½ years after construction was completed. Initially, surface cracking developed in the spillway deck and a portion of the navigation lock and eventually spread over most of the project. At the lock, major structural cracks have developed in the chamber and approach walls and have required extensive repairs (See Figures IV-1 though IV–3). Instrumentation was also installed to monitor structural movements and internal stresses.

Extensive structural repairs and maintenance activities have been necessary over the past 35-40 years to alleviate problems resulting from AAR at the lock. In 1967, three vertical slots were cut in the upper approach wall to decrease stress in the concrete (See Figure IV-4). Tensioned steel bars were used to strengthen the support piers, and the cracks in the concrete were grouted. By 1977, the expansion slots had closed due to continued concrete growth, and the three slots were re-cut in 1979-1980. A fourth slot was also added, and additional steel bars were installed in the upper approach wall support piers.

In 1977, a slot was cut in the lower approach wall to isolate it from the lock. Cracks in the lower approach wall piers were repaired in 1982 by grouting steel bars through the piers between the discharge ports.

Extensive placement of post-tensioned tendons has been conducted over the entirety of the lock. These tendons tie the concrete monoliths together and tie the monoliths to the lock's rock foundation (See Figures IV-5 and IV-6).

Two significant events in 1995 indicate that AAR continues to cause structural and operational problems at the lock. In June of 1995, the lower land wall gate hinge assembly pin almost failed, causing an unscheduled lock closure for repairs. The lock wall had grown in height almost pulling the hinge pin from the gate. If the pin had been fully removed, the gate could have fallen resulting in an extended lock outage of six months or more.

In 1995, studies were completed that evaluated the condition of the powerhouse, spillway, and lock. The results of this study have caused considerable concern about the long-term structural integrity of the lock and have indicated that the lock has a finite life. Additional studies indicate that the probability of an event with unacceptable, possibly even catastrophic, results is increasing. At some point, the probability of such an event would become so great that the lock would be permanently closed to protect the public downstream of the project and the investment in the other features of the project. Such a closure of the Chickamauga Lock would halt commercial navigation on the upper Tennessee River. A catastrophic failure of the lock (possible but highly unlikely) could result in partial loss of the Chickamauga pool and interruption of public and industrial water supplies. A loss or a major drawdown of the pool would have catastrophic impact on the two TVA nuclear power plants that depend on the Chickamauga pool for cooling water. Lowering the pool would result in these plants having to shut down at a considerable expense to TVA and the region serviced by TVA power production. Additionally the hydropower operations of the Chickamauga Project as well as upstream projects would also be drastically impacted.

d. Structural condition of upstream locks. The upstream projects (Watts Bar, Fort Loudoun, and Melton Hill) do not experience AAR. The aggregate used in the construction of these projects came from a different quarry and does not react with the alkali in the cement. Both Watts Bar and Fort Loudoun Projects are about 60 years old (Melton Hill is almost 40-years old) and are in excellent condition. While some significant maintenance activities would be expected over the next 50-years, continued utilization of the projects, including the locks, is not a concern.

3. NEEDS

The need addressed in this study is to provide for continued navigation through the Chickamauga Project and to insure continuation of Chickamauga's other project purposes. As discussed earlier, structural problems associated with Chickamauga Lock are endangering navigation on the Upper Tennessee River.

4. OPPORTUNITIES

The consideration of alternatives for solving the existing lock’s structural problems as addressed in TVA’s 1996 Final Environmental Impact Statement (FEIS) provides the opportunity to address Chickamauga’s poor reliability and inadequate lock size. Through construction of a new lock (as recommended in TVA’s FEIS), the reliability problems associated with AAR problems would be eliminated. Also, by providing a lock chamber size, which could accommodate multiple barges, (greater than the existing 60’X360’) Chickamauga’s inadequate lock size can also be addressed.

The Chickamauga Project has only one chamber, measuring 60 feet wide and 360 feet long (See Figure IV-7). The lock was completed in 1940 to accommodate four standard barges (26'x175'). As discussed in Section III, the towing industry has greatly increased its use of larger, higher capacity barges on the Tennessee River, such as the jumbo barge (35'x195') and the integrated, super jumbo, or tanker barge (52'x290'). The standard barge has virtually disappeared from the Tennessee River. The jumbo barge is designed primarily for the larger locks on the lower Tennessee River and the rest of the inland waterway system. While it is not efficient for the Upper Tennessee River, the economy of the jumbo barge on the remainder of the waterway offsets its costly use on the Upper Tennessee. The Chickamauga Lock chamber will handle only one jumbo barge at a time.

The lockage problems at Chickamauga result from the growth in traffic, barge sizes, and the size and configuration of tows. The small lock at Chickamauga causes increased delays due to congestion and an increase in lock processing time due to multi-barge tow configurations. These lockage problems represent a significant economic loss to the shipping industry and, ultimately, to the consumer. Towing rates for the Upper Tennessee River are about twice those for the remainder of the Tennessee River system.

Chickamauga Lock, as discussed in Section III, has an average tow processing time of 8 hours per tow. This is the highest average locking time in the Ohio River System. For comparison, the average processing time at Nickajack Lock was only 1½ hour per tow. Nickajack processed more than twice the number of tows and almost twice the tonnage of Chickamauga in 1998. Locking time is comprised of both delay and processing time. Only four locks in the Ohio River System have a higher average delay time and none have a higher processing time. However, the average delay time is actually higher than shown in the Corps' Lock Performance Monitoring System (PMS) data. Because of the close proximity of the Chattanooga harbor, up bound tows will wait in the harbor when they know the lock is being utilized by another tow. Since the tow is not at the lock available for a lockage, the tow is not entered into the PMS database, therefore underestimating the actual delay time.

Recreational vessel lockages also compete with commercial tows for locking privileges. Noncommercial lockages, meaning recreation boat and other type lockages, comprise a larger share of lockages at Chickamauga than at other projects on the inland navigation system. Recreational boat and other type lockages in 1998 comprised 44 percent of total lockages at Chickamauga Lock. For special events along Chattanooga's riverfront, the lock is closed to commercial traffic for several hours requiring commercial tows to schedule their operations around these closures. Current locking policy is to lock recreational craft after three commercial locking cycles. For safety reasons, recreational craft are not locked with commercial tows. Therefore, the locking procedure for a commercial tow may be interrupted to allow lockage of a recreational vessel.

The unreliability of Chickamauga Lock resulting from the AAR problem has resulted in industries, in many cases, utilizing more costly modes of transportation. Through traffic studies, TVA has identified 4.3 million tons of commodities, which are moving overland, when they could be moving by water at cost savings. By utilizing a more costly mode of transportation, the cost of goods provided to the nation is higher. Even though not included in the economic analysis, it is possible that industries are locating in other areas of the county at a greater expense because of the lack of a reliable Upper Tennessee navigation system.

5. STUDY OBJECTIVES

The Principles and Guidelines, dated 22 March 1982, stipulate that "The Federal objective on water- and related land-resources planning is to contribute to national economic development (NED) consistent with protecting the nation's environment…." Contributions to NED are direct benefits and costs that accrue to the planning (study) area and the rest of the nation. The Federal objective is further specified in terms of alleviating problems, satisfying needs, and realizing opportunities within the planning area or region. For the Chickamauga Lock Feasibility Study, the specific planning objectives are listed below:

a. Insure continued and reliable commercial navigation at the Chickamauga Lock and Dam Project.
b. Minimize the adverse effects to the navigation industry of maintenance closures at Chickamauga Lock.

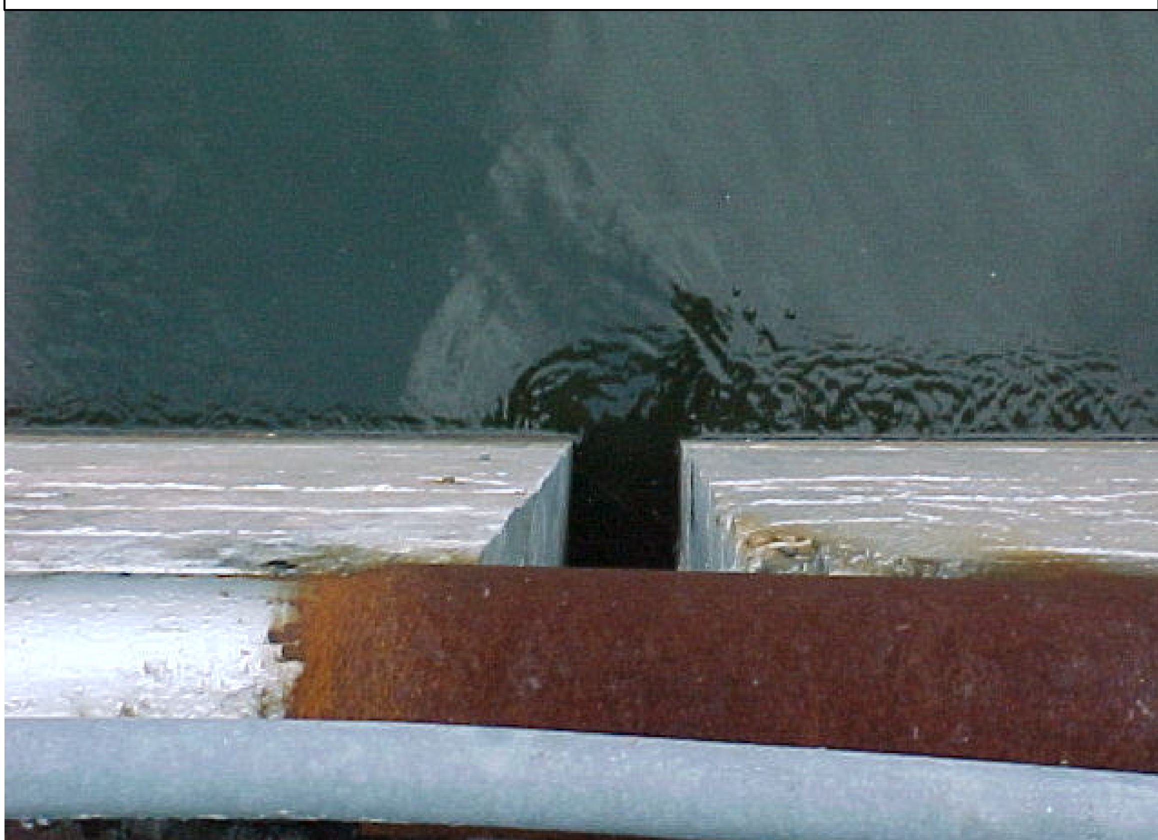
c. Reduce lockage-processing time (cost) to navigation traffic currently using Chickamauga Lock.
d. Facilitate safe and efficient movement of traffic through Chickamauga Lock to the level of demand projected during the economic life of a potential new lock project.
e. Conserve fish and wildlife, recreation, and cultural and natural resources in the Upper Tennessee River Valley.

Figure IV-1 – Crack in the upper end of river lock wall during 1999 dewatering.

Figure IV-2 - Crack in river wall filling and emptying culvert during 1999 dewatering.

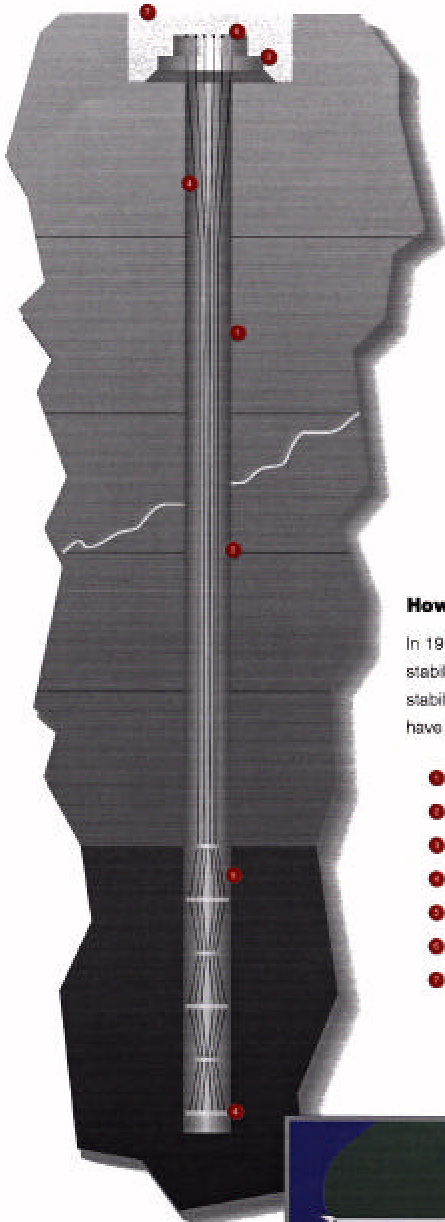
Figure IV-3 – Crack in river wall filling port during 1999 dewatering.

Figure IV-4 – Saw cut through upper guide wall to relieve AAR stresses. Looking down from top of guide wall.

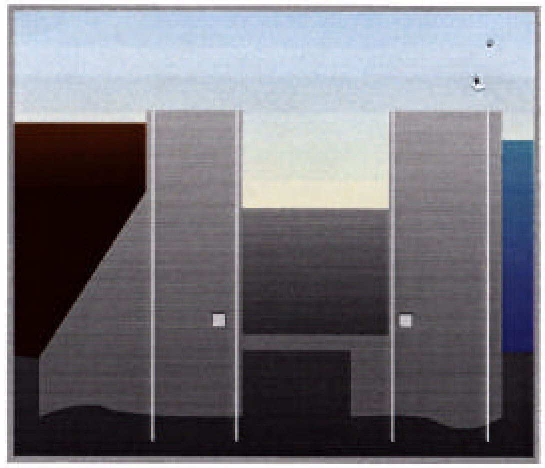


Post-Tensioning Anchoring

Chickamauga Lock



Cross Section of Dewatered Lock with Post Tensioning



How Post-Tensioning Anchoring Works and is Assembled

In 1988, post-tensional anchoring repairs began. The temporary repair measure is used to stabilize and reduce movement of the concrete lock structure. Cracked concrete reduces stability and produces serious deflections. Since 1995, more than 297 post-tensioning anchors have been installed and capped at Chickamauga Lock.

1. Boreholes, measuring 11-inches in diameter, are drilled through concrete into bedrock.
2. The borehole is tested for watertightness.
3. The bearing plate of the anchor head is placed and grouted.
4. Post-tensioning tendons are inserted into the borehole.
5. The post-tensioning assembly is then anchored into the bedrock by grouting.
6. Each tendon cable of the assembly is tensioned.
7. Excess tendon cable is trimmed and the recess is filled with concrete.

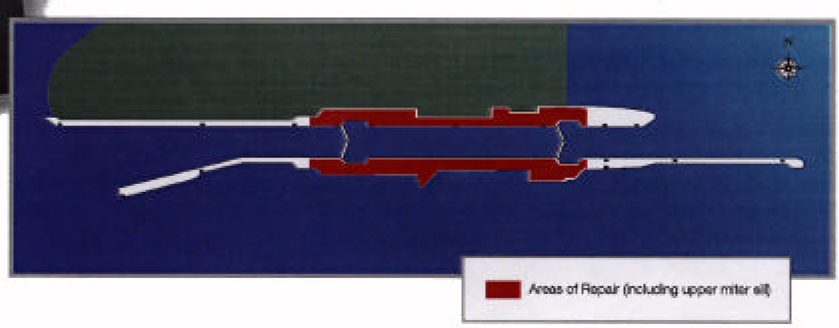


Figure IV-5

Installation of Post-Tensioning Anchors

Figure IV-6

Chickamauga Lock, Tennessee River mile 471.0

Figure IV-7