POTENTIAL IMPROVEMENTS IN THE WATER QUALITY OF THE SAVANNAH RIVER DOWNSTREAM OF THE J. STROM THURMOND DAM

Daniel L. Parrott, Sr.

AUTHOR: Chief, Civil Programs and Project Management Branch, U.S. Army Corps of Engineers, P.O. Box 889, Savannah, Georgia 31402-0889.
REFERENCE: Proceedings of the 2003 Georgia Water Resources Conference, April 23-24, 2003, at the University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, Georgia.

Abstract. Over the years since the Corps of Engineers hydropower plants on the Savannah River have been in operation, successive and recurring failures in the generators and transformers presented a need to look at the overall rehabilitation requirements in order to achieve safe and reliable power production. However, the Corps of Engineers went beyond just the restoration of reliable power production, and has used this opportunity to incorporate both hydropower improvements and environmental restoration as a part of the Major Rehab project.

In order to help offset the low dissolved oxygen (DO) level in the tailrace during the late summer and early fall, the new turbines will employ the new Auto-Venting Technology, as developed by TVA and Voith-Seimens. This technology will provide at least a 2 parts per million (ppm) increase in the DO levels in the tailrace whenever the ambient DO is 3 ppm or less.

With the first of seven units installed, DO testing was initiated in the fall of 2002 to assess the capability of the new turbines to improve the DO levels over a variety of conditions.

Initial tests for the first of seven turbines indicate that the DO improvements exceed expectations. Further tests will be conducted over the next 3 years to determine the total impact of the DO levels on the ecosystem downstream of the J. Strom Thurmond Dam.

INTRODUCTION

The purpose of this paper is to outline the water quality issues that are common to all large dams in the southeast, the process where by the Auto-Venting Turbines were included in with the J. Strom Thurmond Major Rehab Project, the water quality improvements that are already being seen in the tailwater of the dam, and the promise for the future for other projects (both Federal and non-Federal) in the southeast where turbine replacements are contemplated.

BACKGROUND AND RELATED WORK

The J. Strom Thurmond Dam is located on the Savannah River, just 40 miles north of Augusta, Georgia. The J. Strom Thurmond Dam, formerly known as the Clarke's Hill Dam, is one of four U.S Army Corps of Engineers dam that string from just below Augusta, to 120 miles north to the Hartwell Dam and Lake.

Built just after World War II from 1946 to 1954, the J. Strom Thurmond dam forms a lake that is 71,000 acres and has a shoreline of nearly 1,200 miles. The dam and lake are "multipurpose" projects, that is, they are authorized by Congress to provide flood control, navigation, hydropower, water supply, recreation and environmental benefits to the nation and to the peoples of the region.

In 1991, the US Army Corps of Engineers, recognizing that their 1950's era dams, locks and floodwalls were approaching the end of their useful life, began a Major Rehabilitation program to identify the projects that suffered from a loss of reliability or performance, quantify what type of rehabilitation was needed, and to propose to Congress the project scope, schedule and cost of such rehabilitation.

In 1993 through 1994, the Savannah District embarked on the necessary engineering, economic and environmental studies that would outline just which hydropower components had the highest probability of unsatisfactory performance, and the most economical means of solving the problem, be it replacement, refurbishment, or just repair. At that time, opportunities were limited as for environmental restoration or enhancements.

In 1994, the headquarters of the US Army Corps of Engineers approved the Major Rehab Evaluation Report, which outlined the J. Strom Major Rehab Project, at a estimated final cost of $70,150,000. Work immediately began on the required contract documents in order to hire the qualified contractor to perform the work.

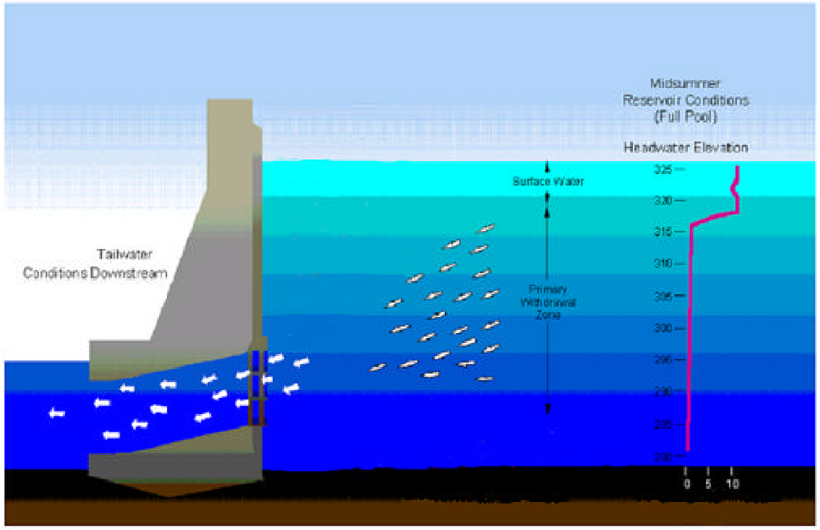

Figure 1. Thermal Stratification at the J. Strom Thurmond Dam.

ENVIRONMENTAL CONCERN

The thermal stratification experienced at the J. Strom Thurmond powerplant is similar to most deep reservoirs in the southeast. Stratification results from the difference in the densities between the surface and surface water caused by the temperature variations in the water column. As the tributary and surface waters warm, the difference in density between the surface and bottom waters begins to restrict the vertical circulation of the lake. The result of this restriction of circulation is the development of three layers of water: the epilimnion, the well-mixed surface layer which receives oxygen from the interaction with the atmosphere; the hypolimnion, the bottom strata which is essentially stagnant water in which the dissolved oxygen is slowly used by the respiration and decomposition of organic matter; and the thermocline, which the transition between the upper and lower strata, and which exhibits the maximum Temperature gradients.

Thermal stratification begins in the J. Strom Thurmond Lake in late April and early May of each year. The thermocline is established at a depth of about 30 to 35 feet below the surface, and is maintained at that depth through early October. After that time, the depth to the thermocline gradually increases until the lake becomes completely mixed and isothermal in early December.

The problem lies next in the location of the water intakes, or “penstocks” that provide water for the hydro turbines. At the J. Strom Thurmond dam, (and at most dams in the southeast US) the penstocks are located below the thermocline and thus they tend to draw only the un-oxygenated water into the powerplant. After passing through the dam, the relatively cool, low DO water enters back in the river through the tailrace.

As a part of the Major Rehabilitation program, the Savannah District attempted in resolve this environmental concern by the proposal of an Oxygen Injection System as a part of the Major Rehab project. However, the purpose of the Major Rehabilitation Program was to address performance and reliability issues, not environmental restoration (which was a separate program). Thirdly, the upfront cost to design and build an Oxygen injection system is on the order of $2,000,000, plus another $400,000 per year for the supply of the liquid oxygen. Over the 50-year life of the Rehab Project, this would have meant an investment of over $22,000,000, which would have made the entire project uneconomic. Our guidance from HQUSACE indicated that we could include only “incidental” environmental improvements at only “minor” costs. Therefore, the final Environmental Assessment called for a reassessment of the oxygen-improving technology during the design of the turbine replacement contract for possible incorporation at a later date.

The Turbine Replacement contract documents were prepared based on these criteria, and the package was advertised for bids in 1997. The selected contractor, Voith Hydro (now Voith-Siemens Hydro), included in their proposal a plan that provided only incidental DO improvement with the introduction of ambient air through the discharge ring. The downside to this technology was that with the introduction of air, the turbine efficiency would drop 4% to 5%, a quite serious drop in output, requiring more water for the same power output. This was the best that we could do.

Not long after the award of the Turbine for approximately Replacement contract for the replacement of the seven hydro turbines, HQUSACE issued a new policy that clarified and expanded earlier policy on environmental improvements and restoration. In that policy statement, it now became possible to go beyond the "incidental" environmental improvements, to propose specified environmental improvements as long as the overall project economic benefits still justified the project. The changes to the project had to be documented and approved by HQUSACE in a report that described the environmental improvements, justified the additional expense through an economic, outlined the scope, schedule and change impacts.

The Savannah District immediately requested a proposal from Voith Hydro to see just what was possible at the Thurmond site. Their proposal, after some negotiations, was included in the Improved Dissolved Oxygen Turbine Letter Report, which was submitted in March 1999. The report, which included a cost change of $7,200,000, was approved in the following June.

SOLUTION TO THE LOW DISSOLVED OXYGEN PROBLEM AT J. STROM THURMOND DAM

At the time of the contract award, Voith Hydro had been engaged with the Tennessee Valley Authority (TVA) on a 10 year research project to investigate which technologies held the most promise in improving the DO levels in the tailrace without high costs in operation and maintenance or a loss in efficiency. Their research has led to the development of the patented AVT, or Auto Venting Turbines, which can provide significant uptakes in DO in the tailrace while minimizing the loss of turbine efficiency.

The AVT technology entails the fabrication of hollow turbine blades. The hollow turbine blades are connected to small holes in the blades trailing edge and to a piping system through the head cover of the Turbine.

The rotation of the turbine from the force of the water, much as a fan will move in the wind, creates small negative pressure regions at the trailing edge of the turbine blade. The negative pressure at this location actually "pulls" ambient air into the water stream. The size and shape of the small trailing edge holes helps the creation of a multitude of small bubbles. These small bubbles, because of their large surface area, allows for a significant uptake in DO in the water.

The ambient, or natural, DO level in the upper pool significantly impacts the amount of uptake in the water. The lower the ambient DO level is, the easier it will be for the water to absorb additional oxygen. Therefore, the goal for each of the turbines is to provide at least a 2 ppm uptake whenever the ambient DO level is at 3 ppm or less. The overall goal is to provide 4 to 5 ppm at all times in the tailrace during the late summer, early fall time period.

One of the things that we discovered through this process is that, with the current topography of the tailrace, having all seven turbines in full operation at one time will "stack" the water in the tailrace up to the point that the turbines will no longer naturally aspirate. However, in looking at the history of the use of the powerplant, over 60% of the time the powerplant was used, only up to four units were used at one time. The frequency of having all seven operated at one time while during the low DO time of the year was less than 1% during any given year. Therefore, it was not considered to be a significant problem.

Last March, the first of seven new stainless steel turbine runners was delivered at the powerplant. By September 2002, the runner was installed and the first battery of tests initiated. The results of the first test runs provide indications that the turbines performed well beyond the minimum requirements. Tests were run with no air, "trickle" (just enough are to offset the negative pressure at the trailing edge), and with one, two or three head pipes. The results indicate that under ambient conditions of 1.5 ppm (no air introduced) last September, the DO uptake, as measured 100 yards down stream, was an additional 4.0 ppm, with a minimal loss of turbine efficiency. As additional turbine replacements are completed and put into operation, additional tests will be conducted in order for the establishment of new operational guidelines for the newly refurbished Hydropower units.

FOR THE FUTURE

It is entirely possible that with the final completion of all seven units in 2006, the powerplant may not be able to operate at least 5 ppm in all cases in all situations. To meet this goal, additional studies are being contemplated that will address any shortfall, if any, in the DO levels in the tailrace. This study will be proposed under the Section 1135 Environmental

Restoration Program, and will focus on what can be done to assure 5 ppm under most if not all conditions. Some of the alternatives include the addition of compressors which would force the air into the water, the installation of an upstream DO injector system, similar to what is in use at the Russell powerplant just upstream, or the "bleeding" of liquid oxygen directly into the manifold system at the head cover, increasing the ambient air DO level entering into the turbines. Further studies will be conducted to determine the scope of any follow-on efforts.

To date, the Savannah, Mobile and Wilmington Districts are all underway with their Major Rehab efforts that include new Turbines. All three US Army Corps of Engineers Districts, as well as the remainder of the US Army Corps of Engineers, are evaluating the best way to design, procure and implement DO improvements at their powerplants.

On April 8th 2003, at their annual conference in Washington DC, the National Hydropower Association (NHA) recognized the J. Strom Thurmond Turbine Replacement contract as their 2003 winner in the Technical Solutions category. This award was bestowed to the Savannah District for utilizing emerging technology and existing Civil Works authorities and programs to address the long standing environmental issues at the J. Strom Thurmond powerplant. The Savannah District will continue to monitor the conditions downstream of the dam in order to ascertain the benefits of the project. We all hope that in a few years that additional awards in the environmental stewardship area will also be earned for the restoration of the aquatic habitat in the tailrace of the J. Strom Thurmond Dam and Lake.

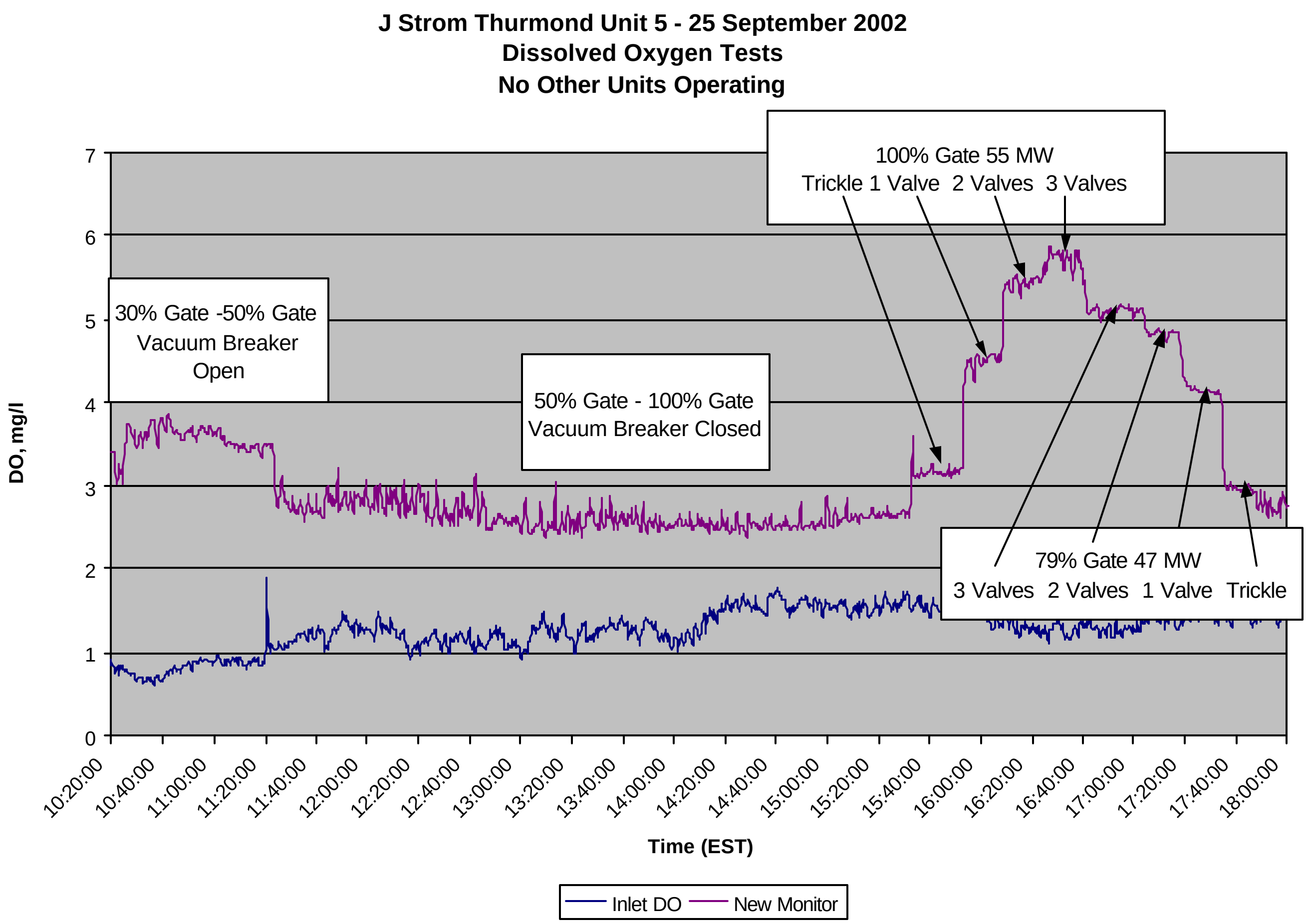

Figure 2. Dissolved Oxygen Improvement as a Function of Gate and Valve Opening.