Appendix D – Evaluation of Scenarios to Warm the Releases From Tims Ford Dam to Improve the Tailwater Conditions for Trout and Endangered Species

Preliminary Report

TENNESSEE VALLEY AUTHORITY
River System Operations & Environment
River Scheduling

EVALUATION OF SCENARIOS TO WARM THE RELEASES FROM TIMS FORD DAM TO IMPROVE THE TAILWATER CONDITIONS FOR TROUT AND ENDANGERED SPECIES

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Site Description and Background Information

Tims Ford Dam is a multipurpose reservoir located on the Elk River in Franklin County Tennessee, in south-central part of the state. The dam is located at Elk River Mile (ERM) 133.3, and is 36.7 river miles downstream of Elk River Dam (Woods Reservoir). Tims Ford dam was completed on December 1, 1970, and the single hydroturbine started producing power in March, 1972.

One of the original purposes for Tims Ford was recreation, and to accommodate this objective, a minimum recreation pool between elevation 888 and 883 ft msl is maintained through October 15 most years. In drought conditions, however, the pool may be lower, as it was in 2007. Recreation in the tailwater below the dam is also of importance to the region, and people are drawn to the area for trout fishing and floating down the river in kayaks or rafts. Several outfitters run float trips in the tailwater. The trout fishery below the dam is stocked by TWRA and can be maintained because Tims Ford dam releases are very cold, due to the depth of the reservoir.

Other species that inhabit the tailwater are less tolerant of the cold water, and their populations are jeopardized and may become extinct if water temperatures in the tailwater are not warmed up.

Dam releases from Tims Ford currently come from four different sources: The large hydroturbine, the small hydroturbine, the sluice, and the spillway. Tims Ford was TVA's first hydroelectric facility retrofitted with a small generating unit for the purpose of maintaining instantaneous downstream minimum flows in response to TVA's 1991 Reservoir Release Improvements (RRI) program to provide a continuous release to the tailwater and improve habitat for aquatic creatures.

Water released from Tims Ford Dam during normal hydropower operations passes through the large hydroelectric turbine and the maximum generating capacity is approximately 4000 cfs. When the large hydroturbine is not in use, water was discharged to the tailwater reach via the small hydroturbine which has a capacity of about 85 cfs, to maintain sufficient wetted area in the channel to prevent distress to aquatic creatures inhabiting the tailwater. The sluice is at the same elevation as the turbines and can provide 80-200 cfs to the tailwater. The large hydroturbine intake centerline is at elevation 751 ft-msl.

Before the RRI Program, the first five to ten miles of the Tims Ford tailwater were generally inhospitable to fish, due to dry channel conditions when the turbine was not in use, and when it was in use, the dissolved oxygen (DO) content of the releases was near zero for much of the summer and fall. Therefore as part of the RRI program, both the small hydroturbine and a DO augmentation system were installed.

The RRI program actually made four modifications to improve the quality of the aquatic environment below the dam. The addition of (1) the small hydro unit, (2) a penstock oxygen injection system, (3) air injection into the large hydro unit via a blower, and (4) air injection into the small hydro unit via an air compressor. A forebay aeration system was installed in 2006 to replace the ailing penstock aeration system.

The Tailwater Issue

The problem is that even though the turbine releases contain adequate oxygen, they are too cold for endangered species such as the boulder darter and several endangered mussels. They are even too cold for some trout species. Therefore, options are being explored to warm up the releases from Tims Ford dam.

Similar problems have been encountered at many hydro projects across the nation and worldwide, and selective withdrawal structures have been added to many of these dams, at great expense, to warm the dam releases.

The intent of this project is to evaluate options for warming Tims Ford dam releases that do not involve capital expenditure. If none of these options provide satisfactory water temperatures to the tailwater, then options involving capital expenditure will be evaluated as well. Evaluated options include using the spillway to release various percentages of the total flow to the tailwater from April 15 to October 15. The spillway draws water from elevation 853 and up, depending on how far the gates are open. This is about 100 feet above the turbine withdrawal zone and consequently releases warmer water than the turbines. Generally the temperature difference between turbine and spillway releases is about 8°C. Still, the spillway crest is 35 feet below the normal summer pool elevation, and therefore is cooler than the water on the surface of the reservoir. Other options involving capital expenditure that could be evaluated to tap into the warmest surface water may include a siphon, surface water pumps and/or a flow curtain.

The target location for providing water warm enough for the bounder darter is approximately ERM 119, around Beans Creek. The 14 miles upstream of that location could likely still be maintained as a trout fishery if the dam releases are warmed somewhat.

Modeled Reaches and Years Evaluated

Two areas of study were evaluated: First, the entire tailwater reach from Tims Ford Dam at Elk River Mile (ERM) 133.3 to the mouth of the river in Wheeler Reservoir was modeled. Additionally, the entire reservoir, extending from Tims Ford Dam at ERM 133.3 to ERM 165.3, was also modeled for this study, using Ce-Qual-W2 to determine impacts of operating changes on the reservoir water temperatures and water quality.

The years 2001 and 2004 were used for the analysis. 2001 was a slightly dry year and 2004 was a wet year, with numerous hurricane remnants passing over the region in the summer. Additionally, monthly water temperature profiles were taken in Tims Ford Reservoir in both of these years through October, providing information on water temperatures of high level releases for the entire season of concern. In 2004 the spillway was actually used in late June and early July to pass flood flows, therefore we have measured water temperature data during this event. The resulting tailwater temperatures were noticeably warmer during the time period when the spillway was used. Figure 1 shows the water temperatures separated into those from spillway, large turbine and small turbine releases.

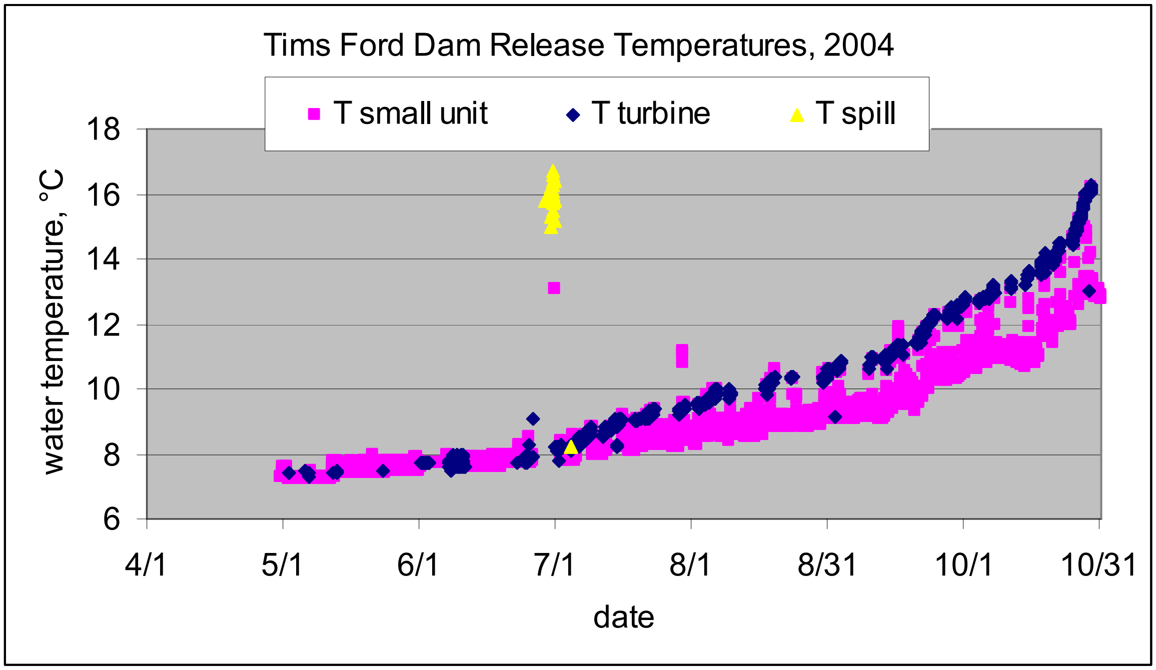

Figure 1. Tims Ford Dam Release Temperatures, 2004

Release temperatures and turbine discharges from the dam are recorded on a continuous basis, and provided a wealth of data for this analysis.

Model Application to Tims Ford Tailwater

The Tims Ford tailwater model involved in this study is a one-dimensional TVARMS ADYN/RQUAL which performs complete hydrodynamic and water quality computations for the modeled reach. The tailwater model utilizes hourly dam release data and hourly release temperature data, as well as hourly meteorology data including dry bulb and wet bulb temperature, wind speed, and solar radiation. Numerous surveyed cross sections are included in the model to depict changes in the river geometry along the reach. At the downstream end of the model, Wheeler reservoir elevations are utilized as a boundary condition.

Model Application to Tims Ford Reservoir

The Tims Ford reservoir model involved in this study is a two-dimensional CE-Qual-W2 model.

The Ce-Qual-W2 model breaks the reservoir down into vertical layers and horizontal segments, forming a grid of cells. Using a graphical post-processor, model results can be displayed in various ways making interpretation of results easy. The reservoir model was utilized to show how changes in the location of the dam release (turbine vs. spillway) would impact water temperatures and water quality in the reservoir.

Evaluated Scenarios

Numerous water temperature simulations had been run for a previous study on the Tims Ford tailwater in 2005 (Montgomery, 2005), and several important lessons were learned from this analysis. The most important results were that turbine use should be as spread out as possible to minimize water temperature impacts in the tailwater. Additionally, the longer the block of turbine generation, the farther downstream the temperature effects occurred. Finally, the results suggested that the spillway *must* be used to help warm the releases.

Therefore for this analysis, turbine releases will be limited to one-hour blocks whenever possible, and all evaluated scenarios include an amount of continuous spill. The scenarios evaluated in this report include:

- Spill 50% of the weekly average flow, release the remainder through the large turbine as evenly spaced as possible,
- Spill 75% of the weekly average flow, release the remainder through the large turbine as evenly spaced as possible
- Spill 100% of the weekly average flow, and do not use the hydro turbine.

50% Spill Scenario

Initial results indicated that the 50% spill option warms the releases considerably over what actual conditions were, and reduces the large temperature fluctuations the tailwater experiences by nearly 50% when the large turbine is turned on, compared to actual conditions.

However this scenario still had water temperatures that were slightly cool for the boulder darter in the late spring and early summer, especially in the months of June and July. Figure 2 shows these water temperature results compared with actual water temperatures for 2001 just below Beans Creek at ERM 119.3. Target water temperatures for the boulder darter based on two biological studies are superimposed on the graph as well (pink blocks). Water temperature fluctuations at Beans Creek are still in the 7-8°C range, which is better than the 15°C change that is common with past turbine usage. Still, 8°C is a large temperature swing and has potential to stress the fish.

75% Spill Scenario

Because the 50% spill scenario still causes some significant temperature fluctuations in the river, a 75% spill scenario was also evaluated. This allows some turbine use, but not as much as the 50% scenario. Results from the 75% spill scenario look slightly more favorable than the 50%

spill scenario in terms of water temperature fluctuations, but in periods of higher flow, temperature fluctuations are still rather significant. Figure 3 shows water temperature results from the 75% spill scenario.

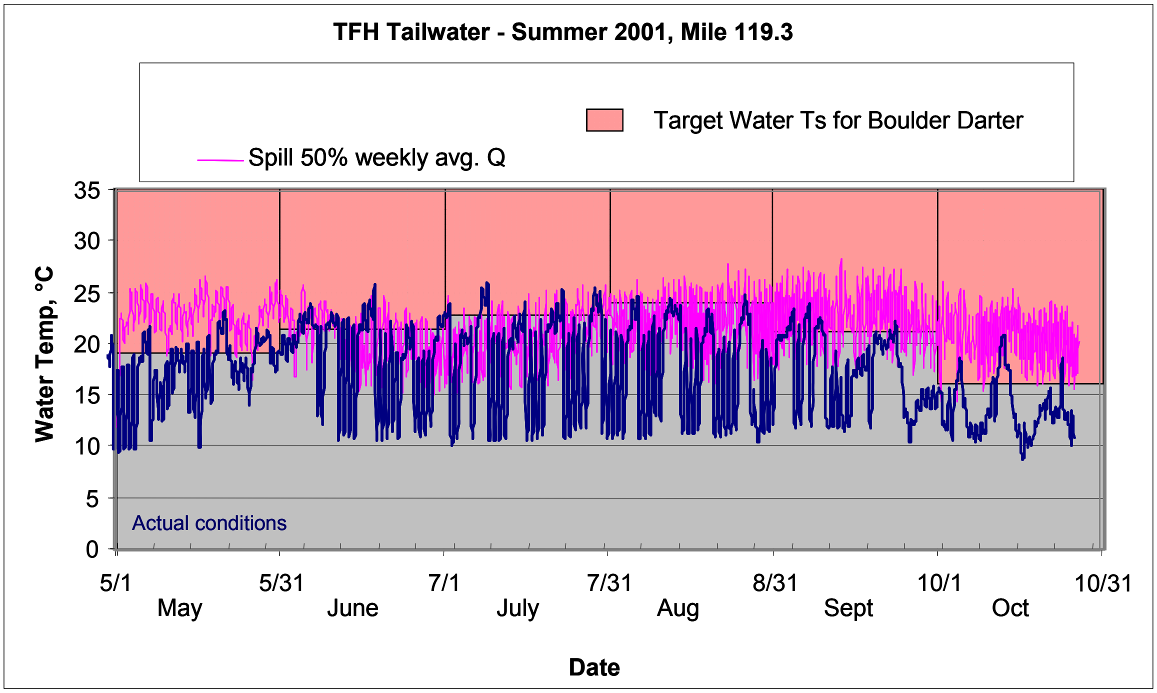

Figure 2. Water Temperatures at Beans Creek, ERM 119.3 for 50% spill scenario and actual conditions

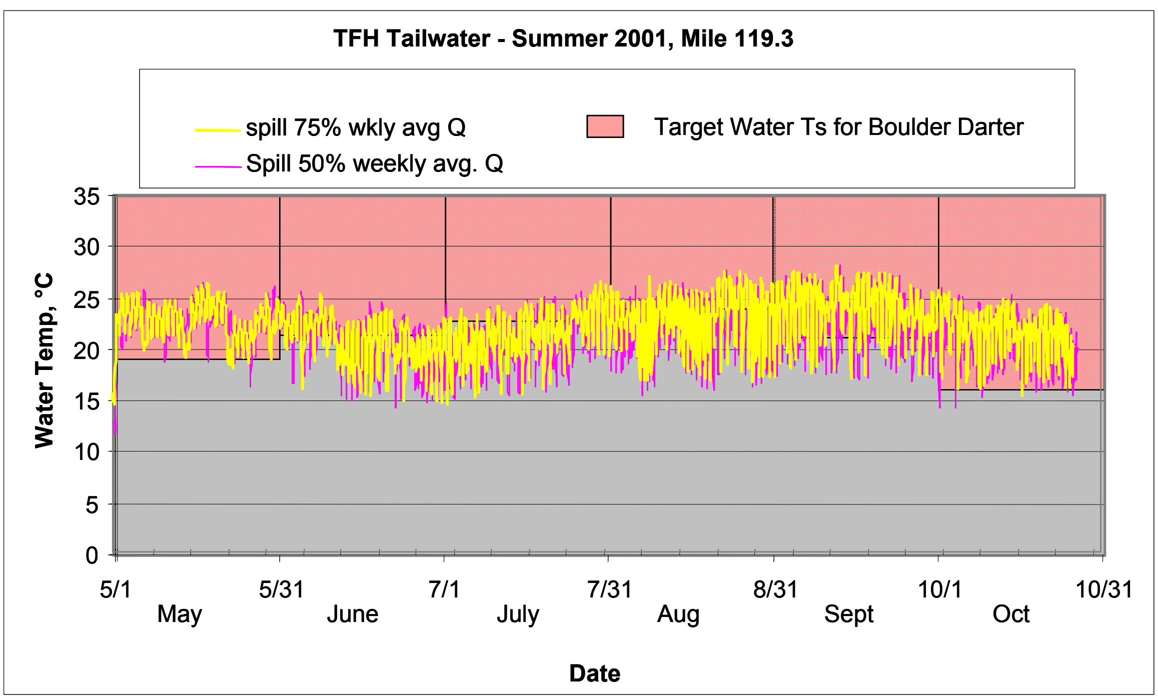

Figure 3. Water Temperatures at Beans Creek, ERM 119.3 for 75% spill scenario and 50% spill scenario

100% Spill Alternatvie

The next scenario evaluated was a 100% spill option. This option would eliminate use of the large turbine completely. Figure 4 shows the water temperature results from this scenario.

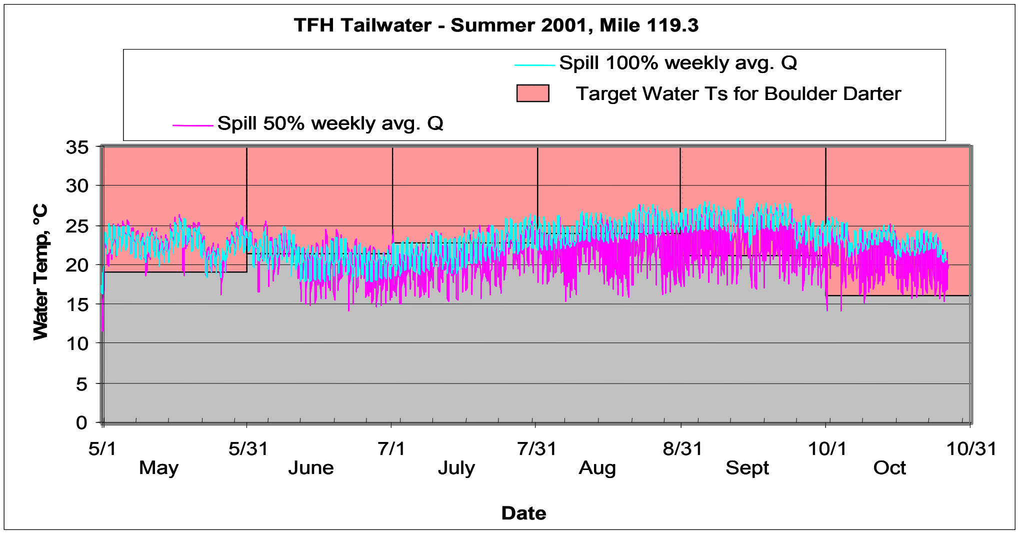

Figure 4. Water Temperature Results at Mile 119.3 for 100% spill scenario

This scenario had essentially the same upper limits on the water temperature as the other scenarios but it reduced the temperature fluctuations even more, since all the water was coming from the spillway, which has significantly warmer water than the low level outlets. Water temperature variations in this scenario are mainly due to diurnal cycles and meteorological events. The modeled option shown in figure 4 does not include a low level release at all.

For water quality purposes, a small release of about 80 cfs *could* be maintained from the sluice to keep low level water moving through the reservoir as well, however this would decrease the maximum water temperature by about one degree C throughout the season of interest. Figure 5 compares the tailwater temperatures at mile 119.3 with and without the 80 cfs sluice flow.

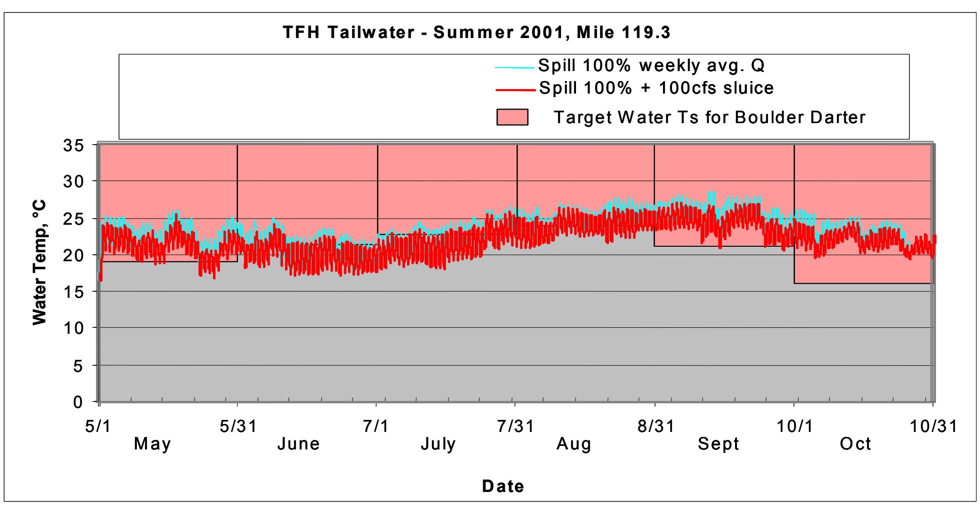

Figure 5. Water Temperatures at Beans Creek with and without 80 cfs sluice release

Either way, target water temperatures for Boulder Darters with this scenario are still not quite being met in June and part of July. This is because the spillway pulls water from 35-40 feet below the water surface, and this water is not as warm as the water right on the surface of the reservoir. Nonetheless, the spillway crest elevation is about 100 feet higher than the turbine or sluice elevation, and the spill water is significantly warmer than the turbine or sluice water. Utilizing the spillway greatly reduces the temperature fluctuations in the river, reducing the thermal shock potential for the fish from a rapid decrease in water temperature.

Proposed Solutions

A blended scenario

The preferred scenario may be a blend of the 100% spill options and the partial turbine use options. 100% spill with a minimal sluice release may be employed until mid-July. Then turbine release may be able to gradually increase, in 25% increments, up to 50% spill by the end of October. During November, the spill may be increased to 75% to 100% depending on the amount of stratification remaining in the reservoir. From December through and including March, the turbines can be used exclusively because the reservoir is generally destratified and uniformly cold during these months.

Water Temperature monitoring

Water temperatures are being monitored at seven locations in the Tims Ford tailwater with Hobos. The Hobo data collectors collect data at regular intervals but do not transmit data by themselves. However a floating station that allows data transmittal via satellite could be installed in the river a short distance downstream of the spillway that transmits data on an hourly basis, for more real-time monitoring of tailwater temperatures. The expense of a floating station would be on the order of several hundred dollars for the equipment, plus installation time and a yearly service contract for data transmittal via the satellite. Labor for assembly and installation in the river is the most expensive part, and the total cost would be less than $5000.

Warming the releases more (with capital expenditure)

The Tims Ford releases could be warmed even more with some capital expenditure. There are several different methods that could be employed to provide additional warming of the spillway releases. Several possible options include a siphon running over the top of a spillway gate, pulling about 100 cfs off of the reservoir surface, an air bubbler system installed on the spillway approach, which is at elevation 830, or a flow curtain attached to the spillway approach deck, and extending upward toward the surface, forcing the spillway to withdraw warmer water from above the curtain elevation.

Siphon

A high level release pulled over the dam with a siphon would have water temperatures about 15 degrees F warmer than the spill releases in the spring, and when blended with the spillway releases, could warm them up by about two to four degrees F during May, June and July. The benefits from the siphon decrease into the late summer and early fall, as water temperatures deeper in the reservoir warm up. Figure 5 shows water temperature profiles from March through September in the reservoir. The three red lines on the plot show the approximate elevations where the turbine, spillway and siphon would pull water from.

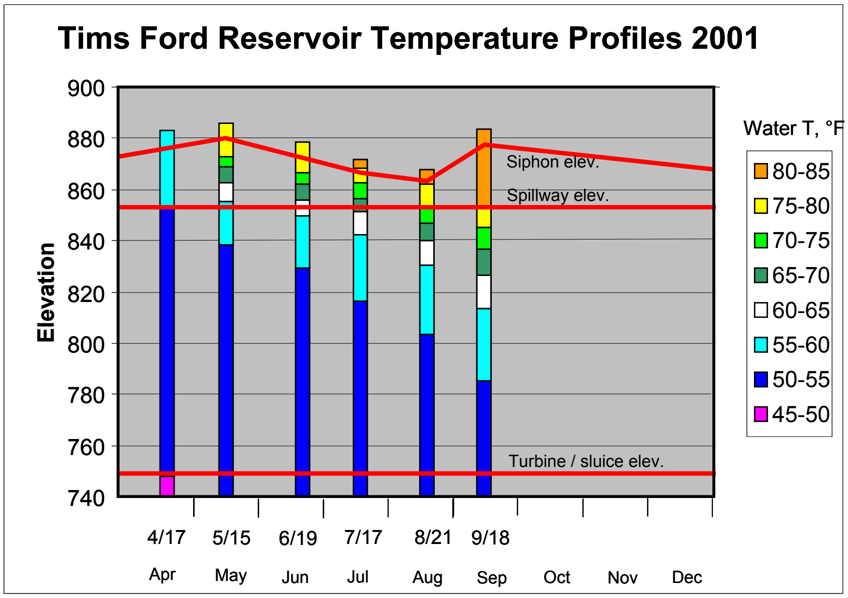

Figure 6. Tims Ford Reservoir Forebay Temperature Profiles, 2001

The siphon inlet could be designed with a flexible intake to remain a fixed distance below the surface, such as at the five-foot depth.

Air Bubbler on Spillway Approach

Another method to increase spillway release temperatures would be to install a small air bubbler system on the spillway approach deck. The approach deck is at elevation 830 and is shown in Figures 6 and 7.

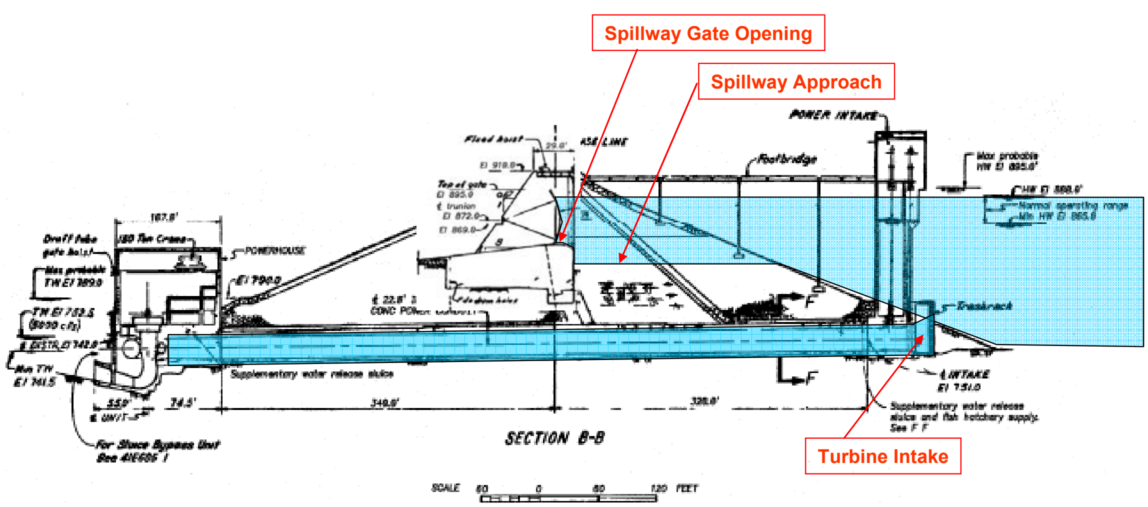

Figure 7. Section of Tims Ford Dam Showing Turbine Intake Pipe and Spillway Approach

Figure 7 shows the spillway approach deck when the dam was under construction.

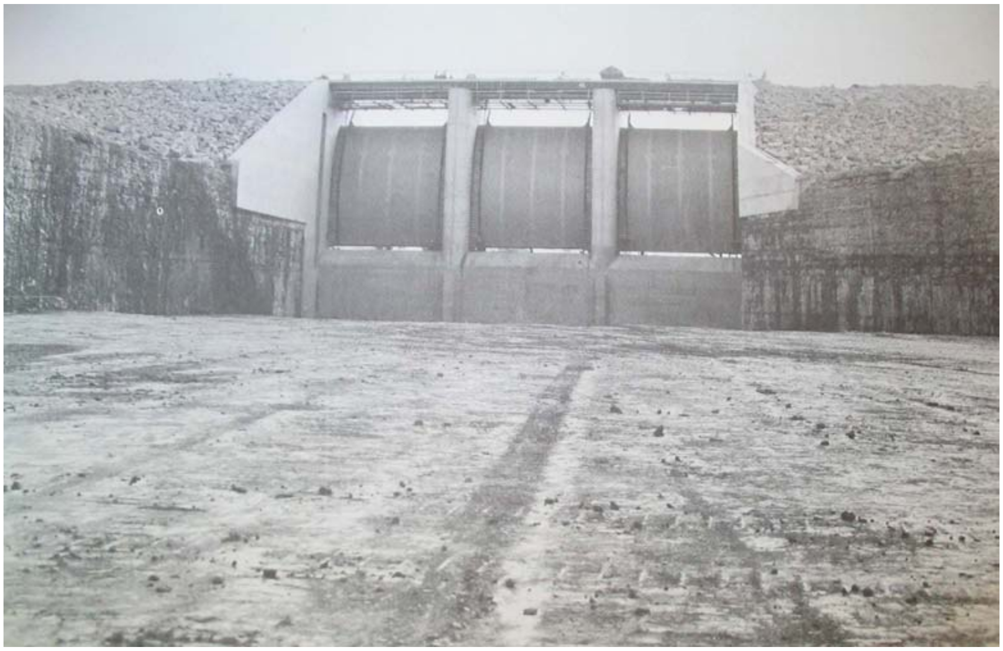

Figure 8. Photo of Tims Ford Spillway Approach

The approach deck is approximately 200 feet long and a minimum of about 140 feet wide. The right wing wall on the spillway is flared outward and the deck width appears to be in alignment with the flare. This space of 200 x 140 feet or more is sufficient to place two rows of air bubblers on. Air, rather than Liquid Oxygen (LOx), would be used, requiring only an air compressor rather than scheduled truck deliveries of LOx, which are costly and hazardous to handle.

A 2004 model study (Montgomery 2004) of Tims Ford Reservoir showed that placing air bubblers at several locations in the reservoir destratified the reservoir somewhat and warmed the water temperature at lower levels in the reservoir by several degrees F, however the warming was at the expense of water quality (decreased DO levels). An all-reservoir system would greatly increase the aeration costs at Tims Ford, which already utilizes a forebay oxygenation system to improve DO content of the dam releases.

However, placing a small air bubbler on the spillway approach deck would mix and warm the water on a smaller scale, for the spillway releases, and would not destroy the water quality of the entire reservoir. If an 80 cfs sluice rate was maintained, the forebay aeration system could continue to be used to aerate the low level releases, and the flow on the spillway would aerate the spillway releases. A 3-D modeling study may be needed to verify the performance of spillway air bubblers on this small scale.

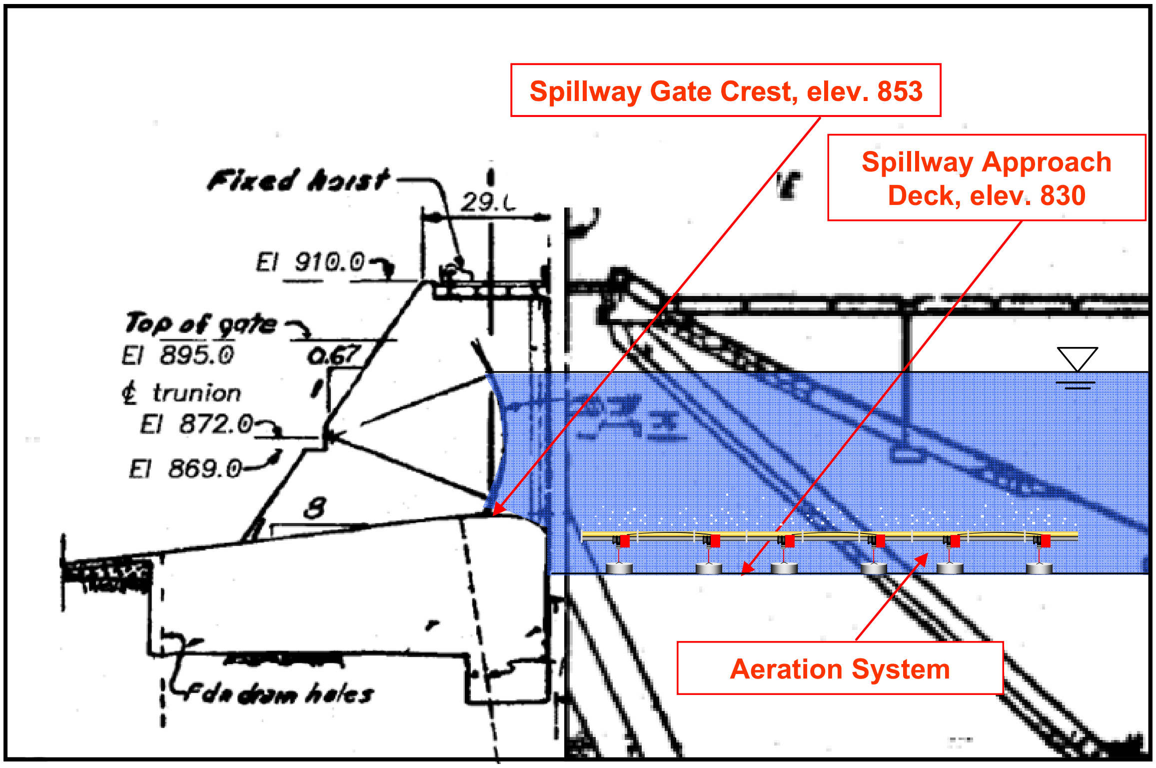

Figure 9. Schematic of Air Bubbler on Tims Ford Spillway Approach

Reservoir Impacts from Changing Water Withdrawal Elevation

Changing *where* the water is removed from the reservoir does have some impacts on water temperatures in the reservoir. Figure 10 shows two snapshots of reservoir water temperatures and DO at different times during the summer for actual conditions in 2001 versus the 100% spill option for the same year. Because the turbines are not being used in the spill option, there is more cool water left in the bottom of the reservoir during the summer, and because more of the upper level water is being pulled through the spillway, there is less warm water near the top of the reservoir. In terms of water quality, the spill only option provides better DO in the reservoir for longer in the year than the actual conditions did.

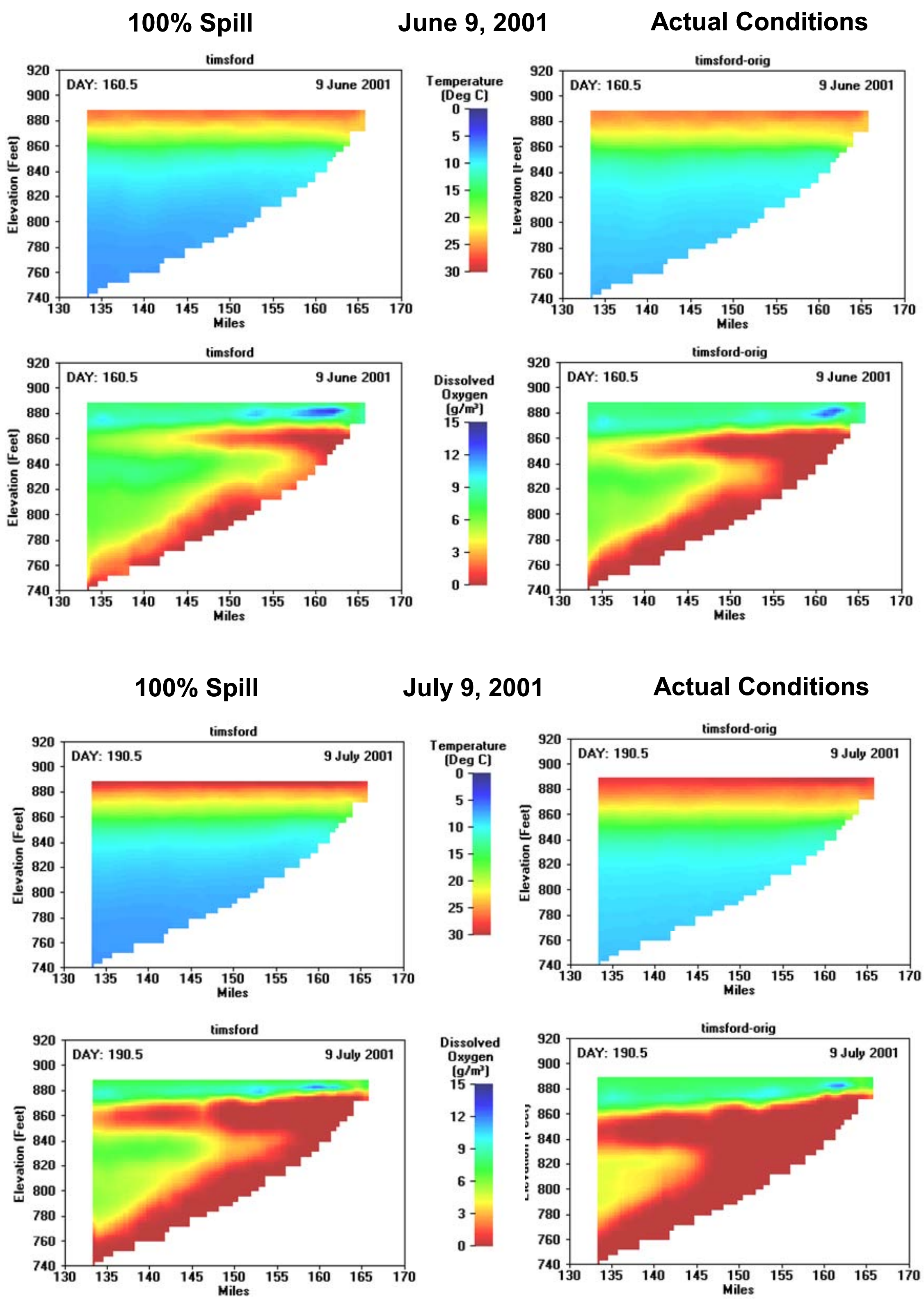

Figure 10a. Reservoir Temperature and DO conditions in June and July 2001 for 100% spill and Actual conditions

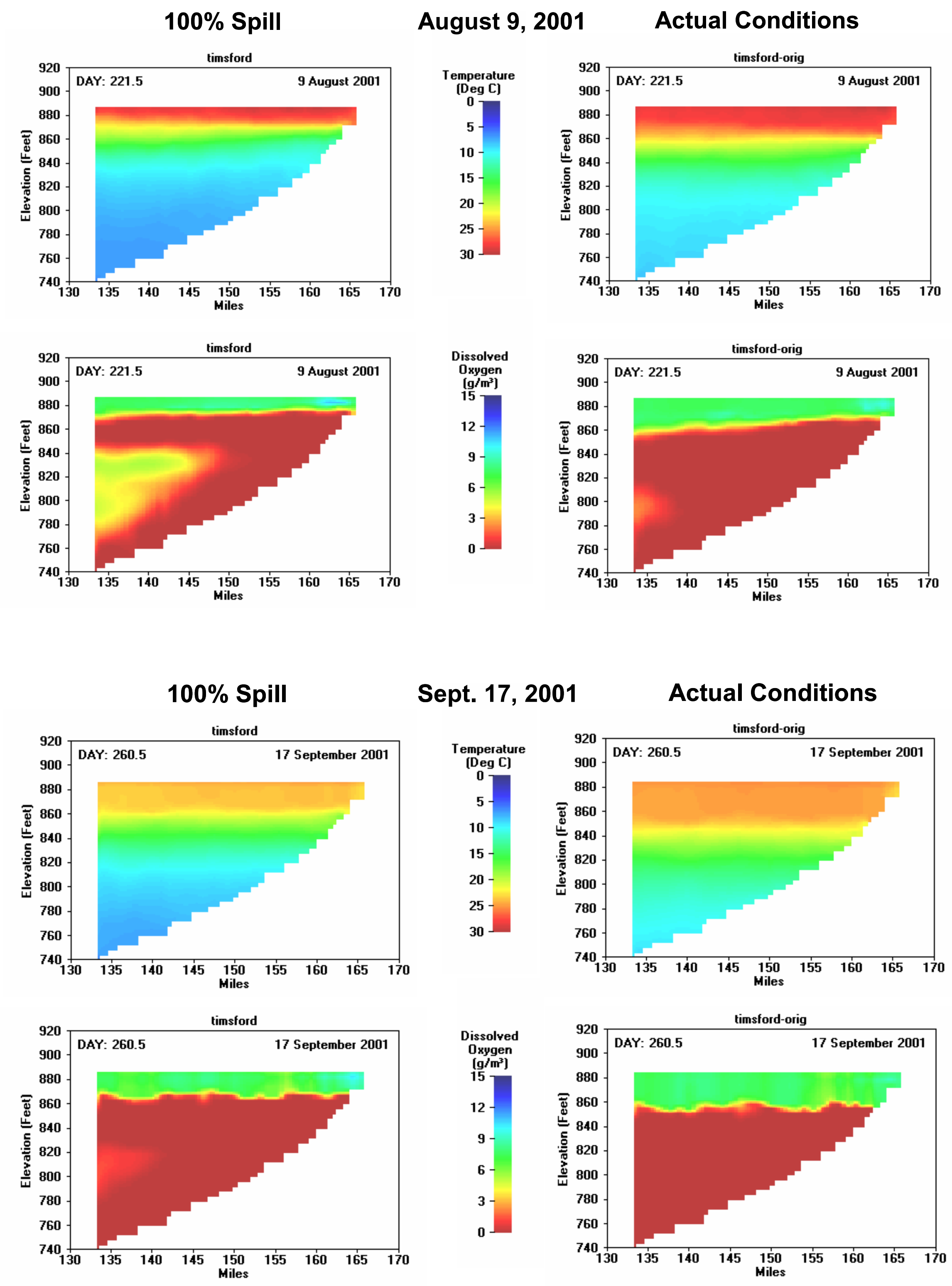

Figure 10b. Reservoir Temperature and DO conditions in August and September 2001 for 100% spill and Actual conditions

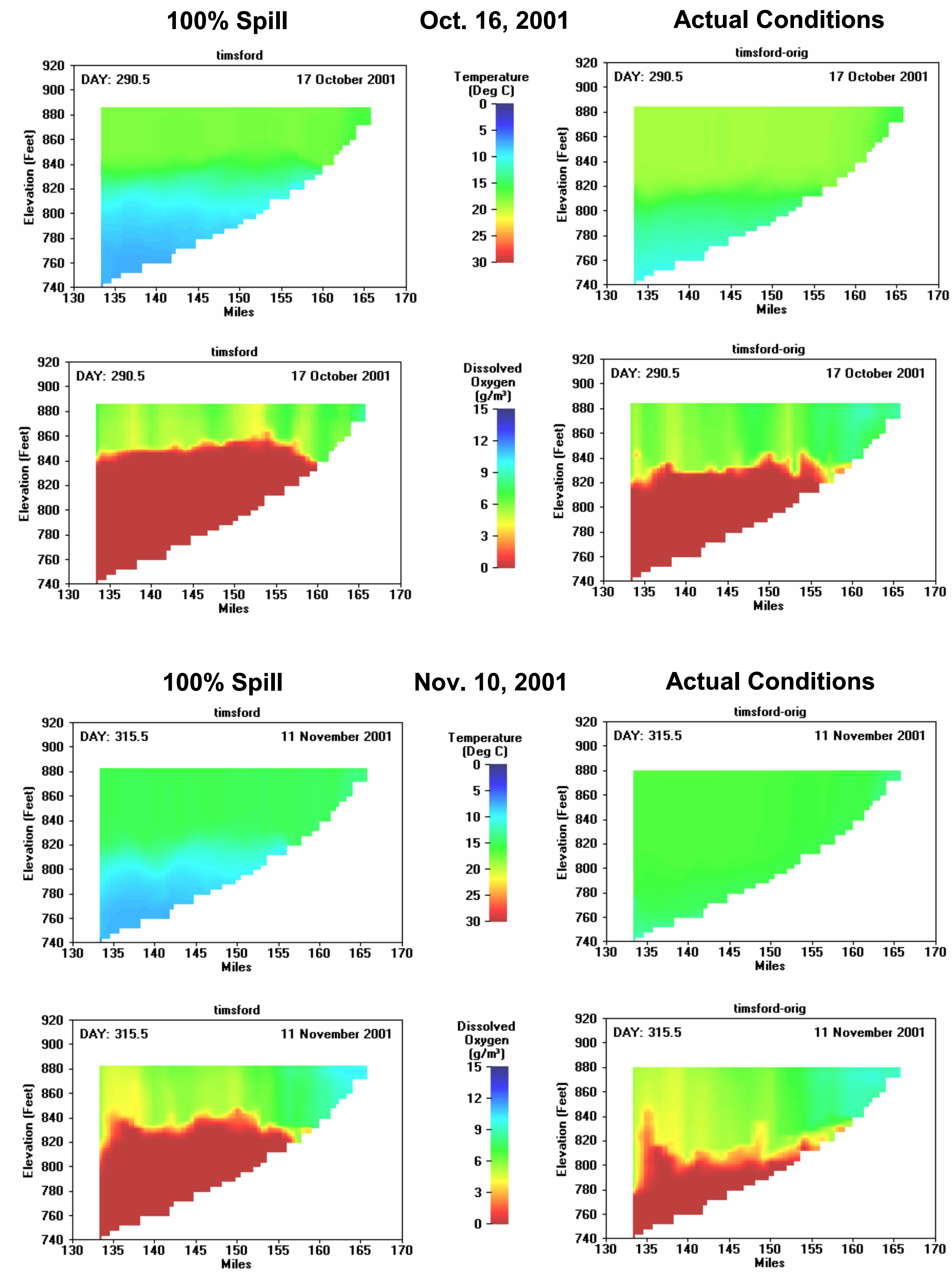

Figure 10c. Reservoir Temperature and DO conditions in October and November 2001 for 100% spill and Actual conditions

Impacts of 100% spill on Tailwater Recreation

Another concern is how changing dam releases might alter tailwater recreation activities. There are presently two major forms of recreation in the Tims Ford tailwater. These are trout fishing and float trips via kayak, canoe or raft. Spilling the weekly average flow, rather than using the turbine, will provide a moderate, steady flow rather than a fluctuation between nearly nothing to a very full channel with swift velocities.

Impacts on Float Trips

The float trip outfitters cannot operate when the large hydro unit is releasing water at Tims Ford. Because of this, TVA has been running only 80 cfs minimum flow from the small unit on weekends. The outfitters can handle a somewhat higher flow as long as it is steady. Figure 11 shows water velocities from steady flows ranging from 200 to 1000 cfs at three locations near the dam. The figure indicates that average channel velocities would range from about 0.8 to 1.3 ft/second at river access areas at 200 cfs, and the velocities would generally range from 1.0 to 2.5 ft/second at 1000 cfs. The 2.5 ft/second at 1000 cfs may be approaching the bounds of an enjoyable float trip for some people, but in general, the velocities appear manageable in this range of flow.

Impacts on Wade Fishing

Because trout are stocked in the Tims Ford tailwater, there is some wade fishing that occurs. A steady flow would be desirable for wade fishing, if the velocity and depth are not too high to prevent safe wading. Depths range from 1.7 to 2.7 ft at 200 cfs, and from 3.5 to 4.2 ft at 1000 cfs. For wading, the product of depth and velocity is generally of concern. TVA generally considers a product of depth and velocity of four or less to be safely wadeable, and depths of more than four feet are generally not wadeable, which would generally rule out wade fishing for flows greater than about 600 cfs in most locations.

At 200 cfs, the velocity - depth product ranges from 1.4 to 3.2, which falls in a safe range of less than 4. At 400 cfs, the product ranges from 1.9 to 5.1. The highest depth-velocity product of the three evaluated locations occurs around river mile 131. Both depth and velocity are higher at this location, indicating either that the channel slope may possibly be steeper or the channel is narrower in that location than the other two locations.

One major factor that influences the safety of wading is a changing flow. If the flows remain steady, this makes the channel easier to negotiate for a wading fisherman than a situation in which the water is rising. If weekly flows were changed at the same time each week, and this time was posted, this would help make the tailwater even safer for wading fishermen.

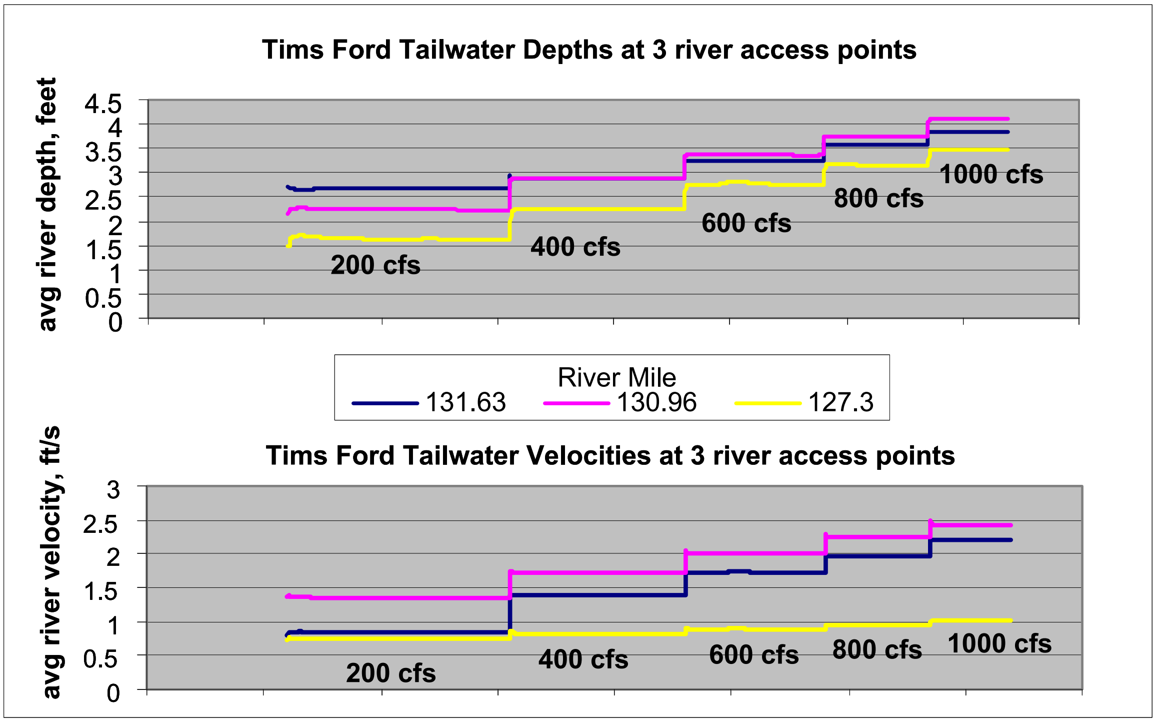

Figure 11. Average Depths and Velocities in Tims Ford Tailwater at 3 access points

Figure 12 shows a comparison of flow-duration curves for the actual conditions versus the 100% spill condition. For the 100% spill condition, the weekly average flow was 1000 cfs or less about 65% of the time, and about 500 cfs or less about 50% of the time. Under actual conditions, releases were about 80 cfs for 75% of the time.

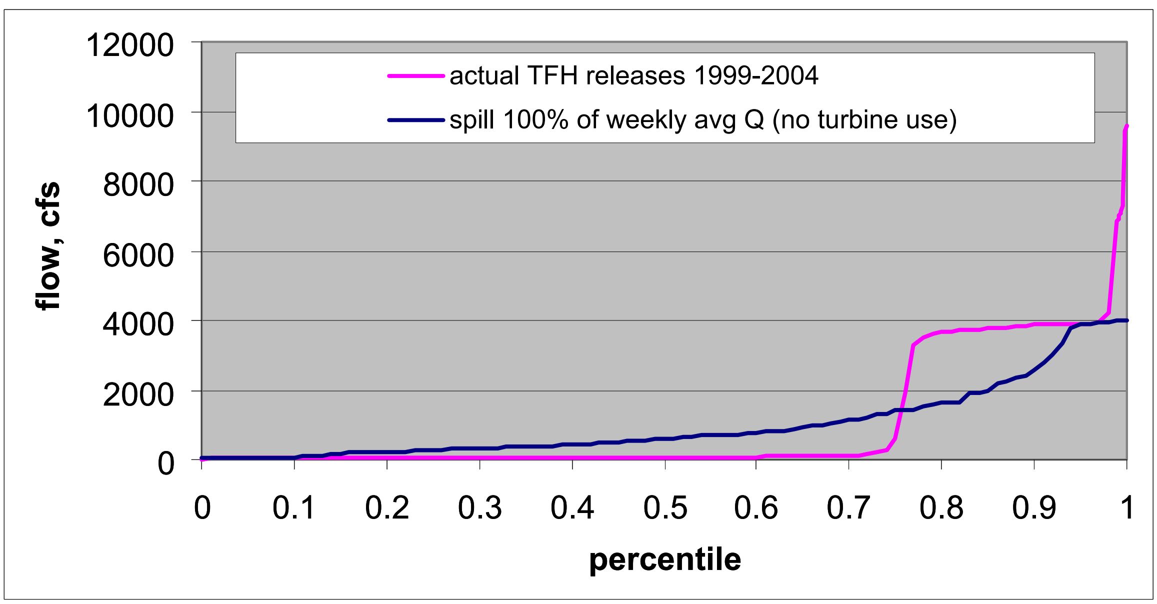

Figure 12. Comparison of flow-duration curves for actual conditions and 100% spill for 1999-2004