SECTION TWO: THE ALTERNATIVES AND THEIR COSTS AND BENEFITS

Chapter 4

Reservoir Operating Policy Alternatives

Many changes in TVA's policies for operating its reservoir system were suggested by members of the general public, lake users of all types, government officials, and TVA staff who participated in this study. By far the most common and widely supported were suggestions to improve minimum flows and dissolved oxygen (DO) in the water released through TVA dams, and to extend summer lake levels in TVA tributary lakes.

This chapter describes the reservoir release policy alternatives and lake level policy alternatives developed in response to these concerns. The effects of these alternatives on the natural and socioeconomic environments described earlier are summarized in Chapter 5; preferred alternatives are identified and explained in Chapter 6; and funding recommendations are presented in Chapter 7.

Other alternatives were identified by participants in the study but not evaluated in detail for one or more of the following reasons:

- they significantly reduced other benefits from reservoir operations that have strong support from the public and their elected representatives;
- the problem or issue could be better addressed in other ways (without changing TVA river and reservoir system policies); or
- they were not feasible.

These alternatives are described at the end of this chapter, along with an explanation of why they were not evaluated in detail.

Reservoir Release Policy Alternatives

Fisheries, waterfowl, and water quality ranked second only to lake recreation in overall concern by the 804 people who attended the 11 public meetings held in the first few months of this study. While interest in fisheries and waterfowl dropped considerably in the two meetings held in TVA's power service area outside the Tennessee River watershed, concern about water quality had broad support in all geographic areas. Water quality was a concern of a variety of interest groups, including groups primarily concerned about other issues. A similar pattern of concern for water quality and aquatic life was found at the 12 public meetings held in February and March 1990 to receive comments on the Draft Environmental Impact Statement (EIS).

In response to these concerns, this study focused on four reservoir release alternatives: continuing TVA's current policies for minimum flows and dissolved oxygen (the "no action" alternative); providing higher minimum flows, plus aeration of releases to increase DO in tailwater areas to a target of 4 milligrams per liter (alternative A); providing the same minimum flows plus aeration of releases and state action to control upstream pollution to achieve a DO target of 5 or 6 milligrams per liter (mg/l), depending on the type of fishery (alternative B); and providing the same minimum flows plus aeration of releases to achieve the 5 or 6 mg/l DO targets without state action to control upstream pollution (alternative C).

Alternative C was added in response to comments on the Draft EIS to clarify the effects of upstream pollution sources on the cost of improving reservoir releases to the 5 or 6 mg/l level. A similar alternative was not added to show the effects of upstream pollution on the costs of achieving the 4 mg/l level in tailwaters because, in the judgment of TVA staff, 4 mg/l is the minimum level needed to assure the survival of a diverse aquatic community in tailwater areas below TVA dams.

Even higher minimum flows than those proposed under alternatives A, B, and C were considered but not evaluated in detail because they precluded lake level improvements for recreation and would have limited effect on tailwater fisheries (see discussion later in this chapter under "Alternatives Not Evaluated in Detail").

The four reservoir release alternatives are described in detail below. The next chapter compares their environmental and socioeconomic effects.

No Action Alternative. TVA's current reservoir release policies for minimum flows and DO are summarized in Chapter 2. Current minimum flows are listed under the heading, "no action" alternative, in tables 19-A and B. TVA's goal for DO, under an agreement with the state of Tennessee, is to provide 4 milligrams per liter (mg/l) in all releases, and to work toward achieving DO levels of 5 or 6 mg/l depending on the type of fisheries. However, this is subject to budget limitations of the state and TVA, and applies only to tailwaters in Tennessee. In reaching this agreement, the state assured TVA that it would not allow stream standards which are attained by the implementation of DO improvements to be violated by increased loadings from permitted dischargers.

Alternatives A, B, and C. Three alternatives to TVA's current reservoir release policies were developed in this study to meet the objectives of improving water quality and aquatic life while allowing for higher tributary lake levels. All three specify self-imposed minimum flow requirements (as opposed to targets) that are higher than the current flow targets. They also more firmly commit TVA to providing higher concentrations of DO than are presently provided. Alternative A sets a target of 4 mg/l in all tailwaters which TVA would provide by aerating releases from its dams. Alternative B sets a goal of 5 or 6 mg/l in tailwaters, depending on the type of fisheries present, which would be achieved both by aeration of releases from TVA dams and by state action to control pollution. Alternative C also sets a goal of 5 or 6 mg/l in tailwaters, which TVA would achieve by aerating releases from its dams, independent of state action to control upstream pollution.

Minimum flow requirements: The same minimum flow requirements for mainstream dams were evaluated for alternatives A, B, and C (see table 19-A). Instead of a single minimum daily average flow target at Chickamauga Dam, plus navigation flow requirements at Kentucky, these alternatives call for seasonal minimum flow requirements at Chickamauga, Kentucky, and Pickwick. These requirements

Table. 19-A
Minimum Flow Requirements from Mainstream Dams

Reservoir	No Action Alternative Year-round Daily Average (cfs)	Observations of Zero Daily Average Flows[1] (#)	Seasonal Minimum Flows Alternatives A, B, and C June-Aug. Biweekly Average (cfs)	May, Sept. Biweekly Average (cfs)	Oct.-April Daily Average (cfs)
Kentucky	--[2]	25	18,000	15,000	12,000
Pickwick	0	2	15,000	9,000	8,000
Wilson	0	0	0	0	0
Wheeler	--[3]	2	--[3]	--[3]	--[3]
Guntersville	--[3]	55	--[3]	--[3]	--[3]
Nickajack	0	1	0	0	0
Chickamauga	6,000	2	13,000	7,000	3,000
Watts Bar	0	19	0	0	0
Fort Loudoun	0	49	0	0	0

Notes:

1. Number of observations from 1940 to 1988, except at Kentucky (from 1944), Nickajack (from 1967), Chickmauga (from 1941), Watts Bar (from 1942), and Ft. Loudoun (from 1943).
2. Approximate minimum daily average flow for navigation is 0 cfs if Paducah, Kentucky, stage on the Ohio River is greater than 16 feet (occurs about half the time); it is 15,000 cfs if stage is less than 16 feet, but more than 14 feet (occurs about half the time); and it is 20,000 cfs if stage is less than 14 feet (occurs only 2 percent of the time). Discharge permits below the dam for water quality are based on 5,000 cfs daily average; Kentucky discharge, in recent years, has never been less than 5,000 cfs in practice.
3. Minimum flow requirements past Browns Ferry Nuclear Plant are 10,000 cfs daily average in the months of July through September; 8,000 cfs daily average in the months of December through February; and 5,000 cfs otherwise.

include a biweekly average minimum flow in the summer that is higher than current daily minimum flow targets and a daily average minimum flow in the winter that is lower than current minimum flow targets. The biweekly summer flow requirements will increase the magnitude of the weekly minimum flows at the other six mainstream dams even though there are no specified requirements at these other dams.

All three alternatives require instantaneous minimum flows (continuous flows every minute of every day) below ten tributary dams that are equal to or higher than the flows currently required, as shown in table 19-B. These instantaneous minimums are equal to between two to eight percent of the discharge of one turbine at these dams operating at peak efficiency; hence, it is impractical to provide this flow through continuous turbine operation. Instead, these instantaneous minimum flows are provided by pulsing turbines for 30 to 60 minutes every four hours at six dams, and by pulsing for 30 to 60 minutes every 8 to 12 hours at four dams where a reregulation weir is advantageous. Allowing time for dampening of the pulsed flows, the instantaneous minimum flows will occur at a distance of two to seven miles downstream of the dam.

Table 19-B
Minimum Flow Requirements from Tributary Dams

Reservoir	No Action Alternative Year-round Daily Average (cfs)	Alternatives A, B, and C Year-round Instantaneous[1] (cfs)
Fayetteville (Tims Ford)	120[2]	120[2]
Tims Ford	80[3]	80[3]
Melton Hill	0	0
Norris	0[4]	200
Knoxville (Cherokee + Douglas)	2,000[2]	2,000[2]
Cherokee	0[4]	325
Ft. Patrick Henry	0[5]	400[5]
Boone	0[5]	400[5]
South Holston	50	90[6]
Elizabethton (Watauga)	112[2]	112[2]
Wilbur	0	107
Watauga	0	0
Douglas	0[4]	585
Chilhowee	1300[7]	1000[8]
Fontana	0	0
Apalachia + Ocoee No. 1	600	600
Ocoee No. 1	0	140
Ocoee No. 2	0[9]	0[9]
Ocoee No. 3	0[10]	0[10]
Copperhill (Blue Ridge)	99[2]	—
Blue Ridge	0	115[6]
Apalachia	0[10]	200[10]
Hiwassee	0	0
Nottely	0	55[6]
Chatuge	0	85[6]

Notes:
1. Instantaneous minimums occur within 2 to 7 miles of the dam provided by turbine pulsing operations and, in some cases, re-regulating weirs.
2. Value is reduced by amount of local inflow between dam and downstream location.
3. Minimum flow provided by small turbine installed for that purpose.
4. Minimum flows shown under alternatives A, B, and C are provided on an experimental basis under TVA's Reservoir Releases Improvement (RRI) program.
5. Releases for contract with Tennessee Eastman Company and for cooling water at TVA's John Sevier Fossil Plant increase flow above stated levels.
6. Candidate for reregulating weir to provide minimum flow.
7. Release is not less than 1300 cfs each day from October through April, nor less than 2600 cfs from 1000 to 2200 hours each day from May to September.
8. Daily average of 1000 cfs from May to October, and 0 cfs from November to April.
9. Recreational floating releases provided between dam and powerhouse.
10. No minimum flows are provided between the dam and powerhouse.

Specific flow requirements related to TVA power plant licensing or permit requirements, contractual arrangements with the Tennessee Eastman Company, and Ocoee No. 2 whitewater recreation continue to be met as under current policy (the no action alternative). No flows are provided in the cutoff tailwaters between the dam and powerhouse at Apalachia and Ocoee No. 3 dams. In the case of Chilhowee Dam, the current minimum flow is reduced to a daily average flow that does not significantly reduce the benefits achieved by the current flow. Operations to provide minimum flows are not performed under flood control conditions; in such cases, these flows are likely to be provided by local runoff.

Dissolved oxygen targets: Under alternatives A, B and C, TVA would provide aeration at two mainstream dams (Watts Bar and Fort Loudoun), four tributary dams classified by the state as having warm water fisheries in their tailwaters (Cherokee, Douglas, Chatuge[1], and Nottely), and ten tributary dams classified as having cold water fisheries in their tailwaters (Norris, South Holston, Watauga, Fontana, Apalachia (below the powerhouse), Hiwassee, Blue Ridge, Boone, Fort Patrick Henry[2], and Tims Ford).

Under alternative A, TVA would provide aeration to achieve a target level of 4 mg/l in the tailwaters from all of these dams. Under alternatives B and C, the DO target would vary depending on the fishery present in the tailwaters. In the tailwaters from the two mainstream dams and the four tributary dams with warm water fisheries, the target would be 5 mg/l; in the tailwaters from the ten tributary dams with cold water fisheries, the target would be 6 mg/l.

Alternative B assumes that the federal and state agencies that regulate pollution sources will take action to control point and nonpoint sources, with the goal of meeting national criteria for water quality established by the U.S. Environmental Protection Agency.[3] EPA's DO criteria establish a range of DO requirements depending on the species and life stages of fish, the frequency and duration of various dissolved oxygen levels, and other factors affecting the fishery.

Under alternative B, TVA would provide aeration to 4 mg/l at those projects where nonpoint sources are contributing significantly to poor water quality (Fort Patrick Henry, Boone, Cherokee, Chatuge, Douglas, Fort Loudoun, Nottely, and Watts Bar). State actions to control pollution would be expected to raise this level to the 5 or 6 mg/l target. Under alternative C, TVA would install additional equipment at these dams to provide aeration to the 5 or 6 mg/l level regardless of state action to control pollution.

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[1]Chatuge is classified by state standards as a warm water fishery, but has a trout fishery in its tailwater.

[2]The first four miles below Fort Patrick Henry are classified as a cold water fishery; however, below this point, the tailwater is classified as a warm water fishery.

[3]U.S. Environmental Protection Agency, <u>Quality Criteria for Water 1986</u>, Report No. 440/5-86-001, May 1, 1986.

These alternatives do not incorporate aeration at the seven lower dams on the Tennessee River (Chickamauga and below) because of concern about the feasibility of available technology and excessive costs. Low DO levels can occur in the releases from these dams, but such occurrences are relatively rare (see table 7). Hence, significant investments in aeration equipment would sit idle most of the time. Moreover, the biweekly average minimum flow requirement for three of these seven dams included in alternatives A, B, and C will help to minimize incidents of low DO (less than 4 mg/l) at all of these dams. Aeration at the two upstream reservoirs on the Tennessee River--Fort Loudoun and Watts Bar--is included in alternatives A, B, and C because minimum flow requirements to control DO concentrations in releases would otherwise require tributary reservoir pool levels to be drawn down in the summer faster than under existing policies.

Research conducted as part of TVA's Reservoir Releases Improvement (RRI) program shows that there are feasible technologies for achieving the targeted DO levels. However, the special circumstances of each dam and tailwater must be considered to determine the feasibility of specific DO improvements and to identify the most efficient and cost-effective method for increasing DO levels.

To estimate the cost of the proposed DO improvements, staff involved in TVA's RRI program were asked to identify the most likely technologies to be chosen to achieve the targeted levels at each of the affected dams. These technologies are shown in table 20, along with projected capital and operating costs for alternatives A, B, and C. If these technologies are used, the capital cost of aeration equipment would range from about $33 million to $54 million for the three alternatives, while operating and maintenance costs would range from about $3 to $6 million annually.

TVA is continuing to evaluate technologies which have the potential of being less expensive than existing technologies at particular dams, and would use the least cost combination of technologies for aeration at each dam if either alternative A, B, or C is chosen. Autoventing turbine technology, for example, currently is being tested at Norris Dam. Pilot project results show that this technology is cost-effective at this facility; hence, it is used in the aeration cost estimate discussed above. If further research and development (recommended in Chapter 6) shows its applicability to other dams, autoventing turbine technology could lower the cost of achieving the proposed DO targets.

Five different aeration technologies are assumed in table 20. *Autoventing turbines* and *draft tube aeration* improve the oxygen content of releases by injecting or drawing air into the flow of water through the dam, either through the hydropower turbine (hence the term "autoventing") or the draft tube, the water passage downstream of the turbine (see figure 6). *Surface water pumps* force warm, oxygen-rich water from the surface of the reservoir into the turbine intakes when turbines are operating. *Oxygen injection*, which is a more expensive technology for aeration, involves transporting and storing liquid oxygen at the dam, converting it to a gaseous state, and injecting it through banks of submerged diffusers in front of the dam when the turbines are operating. *Aeration weirs* are situated downstream of a dam to aerate releases as water passes over them, as well as minimize the need for turbine pulsing to provide minimum flows.

Table 20
Aeration Costs for Reservoir Release Alternatives

Dam	Technology	Costs (1990 $s) Alternative A Annual ($m)	Alternative A Capital ($m)	Alternative B Annual ($m)	Alternative B Capital ($m)	Alternative C Annual ($m)	Alternative C Capital ($m)
South Holston	Oxygen Injection	0.1	0.7	–	–	–	–
	Aeration Weir[1]	–	–	0.2	2.5	0.2	2.5
Chatuge[2]	Aeration Weir[1]	0.2	2.8	0.2	2.8	0.3	3.5
Boone/Ft. Pat Henry[2]	Oxygen Injection	0.2	2.3	0.2	2.3	0.4	3.9
Nottely[2]	Aeration Weir[1]	0.2	2.8	0.2	2.8	0.3	3.5
Blue Ridge	Oxygen Injection	0.1	0.4	–	–	–	–
	Aeration Weir[1]	–	–	0.2	2.8	0.2	2.8
Watauga	Oxygen Injection	0.1	0.7	0.1	1.0	0.1	1.0
Norris	Autoventing Turbine	0.1	1.0	0.1	1.0	0.1	1.0
	Oxygen Injection	–	–	0.3	3.0	0.3	3.0
Hiwassee/Apalachia	Oxygen Injection	0.2	1.3	0.2	2.3	0.2	2.3
Fontana	Oxygen Injection	0.3	2.8	0.5	3.8	0.5	3.8
Douglas[2]	Surface Water Pumps	0.2	2.3	0.2	2.3	0.2	2.3
	Oxygen Injection	0.3	2.0	0.3	2.0	0.6	4.0
Cherokee[2]	Surface Water Pumps	0.2	2.5	0.2	2.5	0.2	2.5
	Oxygen Injection	0.3	4.2	0.3	4.2	0.6	6.2
Watts Bar/Ft. Loudoun[2]	Draft Tube Aeration	0.6	7.0	0.6	7.0	1.1	10.0
Tims Ford	Oxygen Injection	0.1	0.5	0.2	1.7	0.2	1.7
Total		3.2	33.3	4.0	44.0	5.5	54.0

Notes:
1. In addition to aeration, weirs regulate the river flow to minimize the need for pulsing to provide minimum flow.
2. For alternative B, TVA aerates to 4 mg/l, with additional improvement to the 5 or 6 mg/l target level resulting from state action to control upstream pollution. For alternatives A and C, TVA unilaterally aerates to the 4 mg/l and the 5 or 6 mg/l target independently of state action.

In some cases, more than one technology is used at a dam. At Norris, Douglas, and Cherokee, surface pumps or autoventing turbines provide the first two to three mg/l of aeration needed at a dam and oxygen injection provides the remainder until the DO target level is reached. At South Holston and Tims Ford dams, cost estimates are based on the continued use of current aeration methods. At these two dams and the other eight dams classified for cold water fisheries, surface pumps were not chosen because they force warm surface water into the turbine intake, which would increase the temperature of the turbine discharge and the tailwater.

Lake Level Policy Alternatives

Lake recreation ranked at the top of the list of concerns expressed by people who attended the public meetings held at the beginning of this study. This concern focused on lake levels throughout the year and on how reservoir operation for the statutory purposes of navigation, flood control, and power production affects recreation on TVA lakes. Over half of the people who attended the public meetings specifically mentioned lake levels as a concern. About 85 percent of all participants came to one of the four meetings held in tributary areas where concern about lake levels is the highest. Lake recreation also was among the subjects mentioned most often at the public meetings held in February and March 1990 to review the Draft EIS.

Three alternatives to TVA's current lake level policies (the "no action" alternative) were developed and evaluated. Under each, ten tributary reservoirs would be filled more aggressively after the winter flood season to reach the highest pool levels possible on Memorial Day (subject to flood control and minimum flow constraints). Unrestricted drawdown would begin on each of the ten reservoirs on August 1 under alternative 1, on Labor Day under alternative 2, and on October 31 under alternative 3.

Under these three alternatives, tributary reservoirs would continue to be treated uniformly, as under TVA's current policy. This would not be true, however, under four additional alternatives subsequently developed in response to particularly strong interest in extended lake levels in certain tributary areas expressed during public review of the Draft EIS. Under these alternatives, labeled 1A, 1B, 1C, and 1D, unrestricted drawdown would begin on August 1 for most tributary reservoirs but would be delayed until October 1 on others.

No alternatives to current lake level policies during the winter months on either mainstream or tributary lakes were evaluated because of the potentially high loss in flood control benefits provided by reservoir operations to the city of Chattanooga. As discussed later in this chapter, this is because the value of winter flood storage in Chickamauga, Watts Bar, and Fort Loudoun reservoirs is much higher than in other mainstream reservoirs.

The lake level policy alternatives evaluated in this study are described in detail below. Their environmental and socioeconomic effects are compared in the next chapter.

No Action Alternative. TVA's current lake level policies affecting tributary reservoirs are summarized in Chapter 2. Low lake levels during the winter months provide storage capacity for winter floods. Lake levels then rise during the spring months, normally reaching their peak around Memorial Day.

The stored water is gradually released to augment the smaller river flows of summer and fall. The rate of drawdown after Memorial Day depends on the economical use of hydropower and downstream water supply and navigation needs. When it is reasonably consistent with the three primary purposes of flood control, navigation, and power production, water levels can be regulated to achieve numerous secondary objectives (for example, to enhance recreation and fisheries or control mosquitos and aquatic growth). Lake levels must return to flood control guide levels by January 1 of the following year.

Alternatives 1, 2, and 3. Three alternatives to TVA's current lake level policies were developed originally to meet the objectives of promoting better fisheries, better recreation, and increased economic growth based on recreation and tourism in tributary lake areas during the spring, summer, and fall months.

Mainstream reservoirs would not be affected under any of these alternatives. This is because navigation requirements already restrict drawdown on these lakes. As a result, mainstream lakes fill earlier and drop only a few feet from summer "full pool" to winter flood season levels, as noted in Chapter 2. Minor changes to the management of lake levels on mainstream reservoirs have been and will continue to be evaluated on a case-by-case basis in the context of current lake level policies for these reservoirs.

The three lake level alternatives would affect the ten tributary reservoirs which are subject to significant summer drawdown--Norris, Cherokee, South Holston, Watauga, Douglas, Fontana, Blue Ridge, Hiwassee, Nottely, and Chatuge. These lakes would be filled more aggressively to reach the highest possible Memorial Day pool levels. Beginning in mid-March, as under existing policies, they would be filled as quickly as possible, as long as lake levels do not exceed flood control guide levels (which are higher in the spring). If low rainfall prevents lakes from filling at the desired rate, only the hydropower generation needed to meet minimum flow requirements would be permitted, except for certain critical power system needs (to be discussed subsequently).

The rate of drawdown after Memorial Day would be adjusted as necessary to keep lakes above a certain target level suitable for recreation. If lake levels were to fall below this range due to low rainfall or high power demand, hydropower generation would be limited to that needed to meet minimum flows, except for critical power needs. If lake levels were above the target level, drawdown would depend on the economical use of hydropower and the needs for downstream water supply and navigation.

Recreation target levels begin on Memorial Day for all three alternatives, but end at different times. Recreation target levels would end and unrestricted drawdown would begin on August 1 under alternative 1, on Labor Day under alternative 2, and on October 31 under alternative 3.

Alternatives 1A, 1B, 1C, and 1D. Four additional alternatives were developed after public review of the Draft EIS to evaluate the effects of improving lake levels beyond August 1 on four different subsets of tributary lakes. Alternatives 1A through 1D are the same as alternative 1 described previously, except that unrestricted drawdown would be delayed until October 1 on Knoxville area reservoirs (Norris, Cherokee, and Douglas) under alternative 1A, on Tri-Cities area reservoirs (South Holston and Watauga) under alternative 1B, on Fontana reservoir under alternative 1C, and on Hiwassee basin reservoirs (Blue Ridge, Hiwassee, Nottely, and Chatuge) under alternative 1D. Changes in the operation of John Sevier Fossil Plant, which relies on Tri-Cities area reservoirs for cooling water (see Chapter 2), are incorporated into Alternative 1B to assure that recreation target levels (to be discussed subsequently) can be met with equal frequency for alternatives 1A through 1D.

Other lake level alternatives could be developed, under which individual lakes would be treated differently as under alternatives 1A through 1D. However, the effects on the natural and socioeconomic environment would be within the range of effects evaluated for alternatives 1, 2, and 3 as long as the duration of lake levels is shorter than the latest drawdown date (October 31) and recreation target levels are less than or equal to the highest recreation targets shown in table 22 (to be discussed subsequently).

Effect of lake level alternatives on lake elevations: Table 21 and figure 10 show how the lake level alternatives would affect drawdown and lake elevations. Table 21 shows that drawdown during the summer would be moderately reduced under alternatives 1 and 1A through 1D, and significantly reduced under alternatives 2 and 3. Drawdown during the fall would be moderately reduced under alternatives 1, 1A through 1D, and 2, and significantly reduced under alternative 3. Figure 10 uses Cherokee reservoir as an example to show the lake level that would be achieved 50 percent of the time (the median) and the lake level that would be achieved 90 percent of the time for each week of the year under alternatives 1, 1A, 2, and 3. (Appendix B contains the corresponding figure for the other nine tributary reservoirs affected by the lake level alternatives). The median curves in figure 10, from which the drawdown statistics in table 21 were derived, show improvements in the lake level achieved. The 90-percent curves show even greater improvement, indicating that lake levels can be improved in all but the driest years.

Extending summer pool levels an additional two months on selected tributary reservoirs, as specified under alternatives 1A through 1D, could result in some additional drawdown on those reservoirs on which unrestricted drawdown would begin on August 1. This could occur during critical power supply conditions in August and September. However, the increased drawdown should be no more than a few tenths of a foot over the drawdown specified for these reservoirs under alternative 1 (shown in table 21, figure 10, and Appendix B).

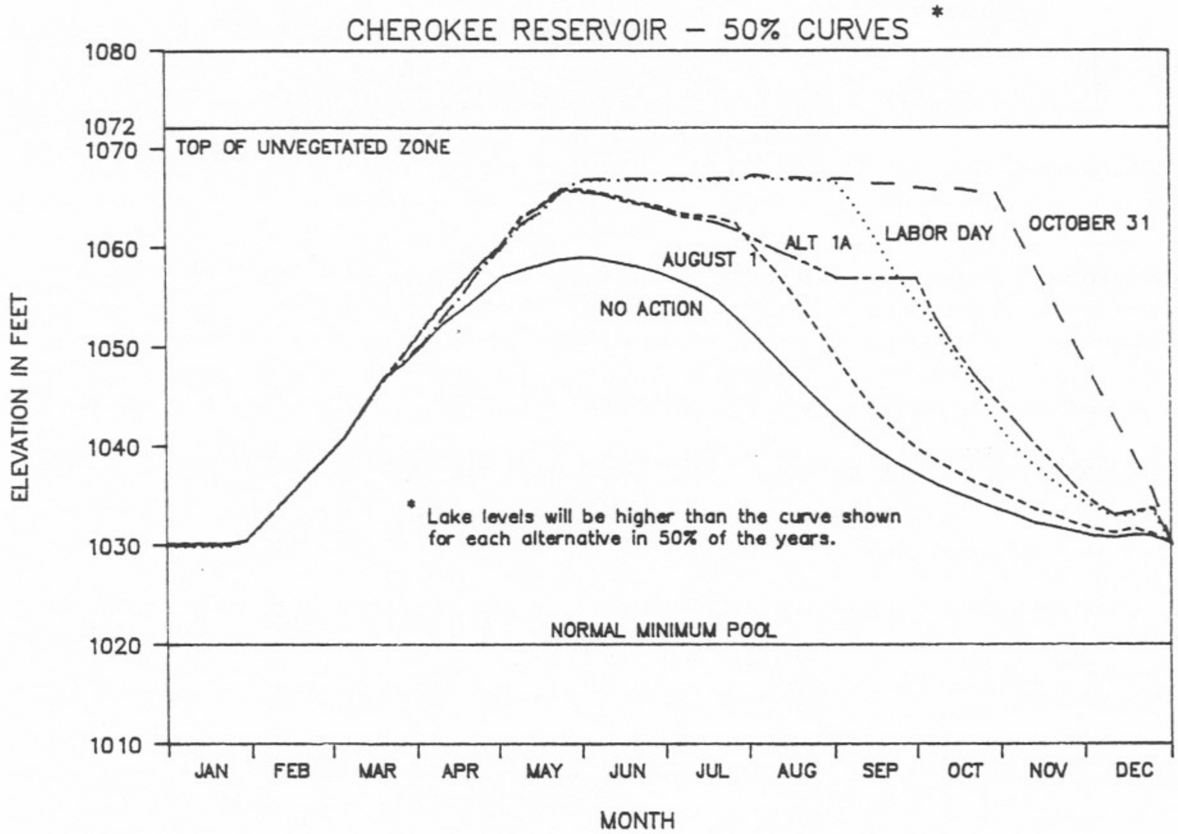
Also shown for reference in figure 10 and Appendix B are the normal minimum level and the approximate elevation of the top of the unvegetated zone on each reservoir (see figure 7). The top of the unvegetated zone, a highly visible feature on TVA reservoirs, is approximately equal to the normal maximum level shown in figure 7. Lake levels will reach the top of the unvegetated zone on the ten tributary reservoirs affected by the alternatives in about 20 to 30 percent of the years under alternatives 1, 1A through 1D, 2, and 3, compared to about 10 to 20 percent of the years under current operations. Reaching the top of the unvegetated zone is not possible in most years due to rainfall. This is particularly true at Fontana reservoir, where the top of the unvegetated zone is at the elevation of the top of flood gates; hence it would not be exceeded except in an extreme flood situation.

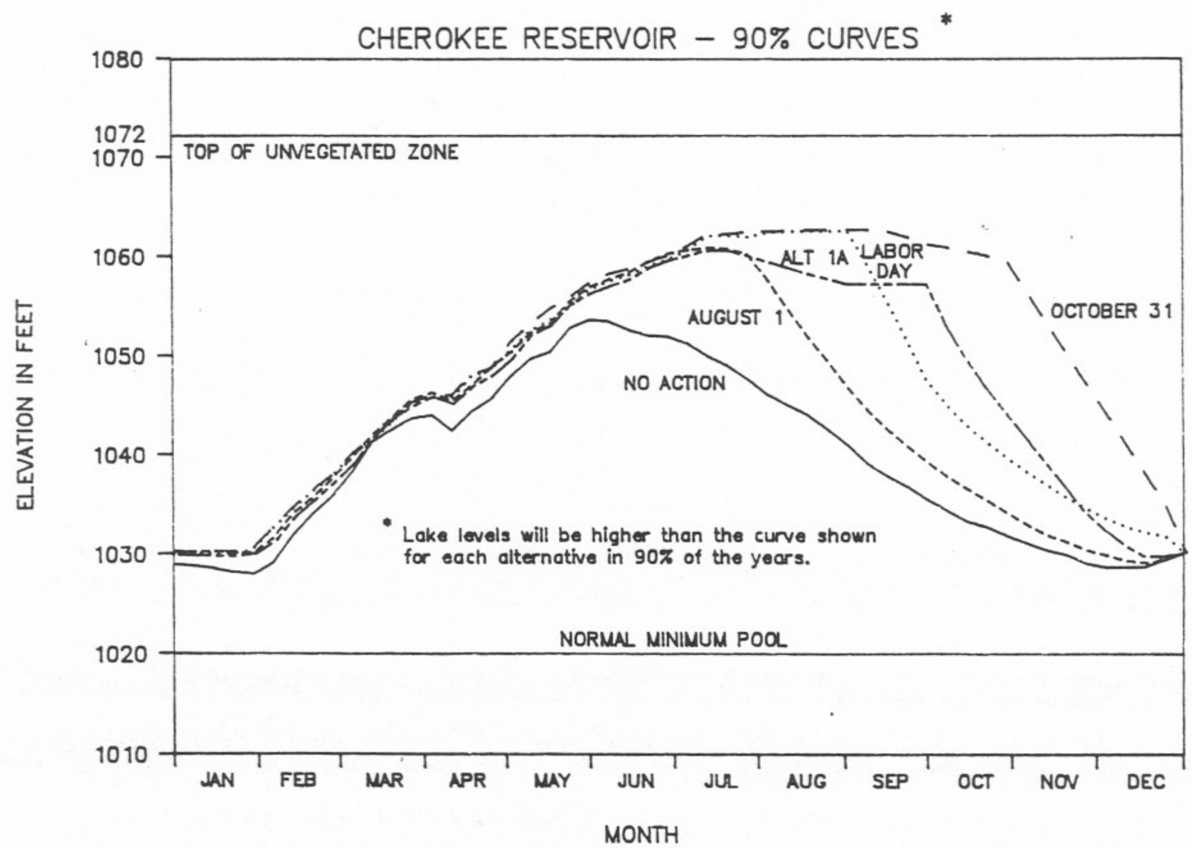
Table 21
Effects of Lake Level Alternatives on
Memorial Day Elevation and Summer and Fall Drawdown

Tributary Reservoir	Alternative	Median Memorial Day Level (ft.)	Average Drawdown on Aug. 1 (ft.)	Labor Day (ft.)	Oct. 1 (ft.)	Oct. 31 (ft.)
Blue Ridge	No Action	1690	6	15	23	33
	Alt. 1	1690	4	11	20	31
	Alt. 1D	1690	3	10	11	22
	Alt. 2	1690	1	1	10	20
	Alt. 3	1690	1	1	2	3
Chatuge	No Action	1925	4	7	9	11
	Alt. 1	1926	2	7	9	11
	Alt. 1D	1926	2	4	4	9
	Alt. 2	1925	0	0	5	8
	Alt. 3	1925	0	0	1	1
Cherokee	No Action	1059	6	16	22	25
	Alt. 1	1066	4	17	26	31
	Alt. 1A	1066	4	9	9	21
	Alt. 2	1067	0	0	12	24
	Alt. 3	1067	0	0	1	1
Douglas	No Action	993	9	23	32	39
	Alt. 1	996	5	21	32	39
	Alt. 1A	995	4	10	10	24
	Alt. 2	995	0	0	13	26
	Alt. 3	995	0	0	1	2
Fontana	No Action	1693	15	31	43	58
	Alt. 1	1704	10	29	47	64
	Alt. 1C	1701	7	15	15	47
	Alt. 2	1699	0	0	15	44
	Alt. 3	1699	0	0	3	5
Hiwassee	No Action	1518	6	13	21	31
	Alt. 1	1521	5	13	22	31
	Alt. 1D	1520	3	9	9	21
	Alt. 2	1519	0	0	7	18
	Alt. 3	1519	0	0	2	3
Norris	No Action	1014	9	22	29	33
	Alt. 1	1017	6	22	32	36
	Alt. 1A	1017	6	10	10	27
	Alt. 2	1016	0	1	15	31
	Alt. 3	1016	0	1	2	3
Nottely	No Action	1768	5	11	15	19
	Alt. 1	1775	4	11	16	21
	Alt. 1D	1775	3	7	7	15
	Alt. 2	1775	0	0	7	14
	Alt. 3	1775	0	0	1	3
South Holston	No Action	1725	8	17	25	32
	Alt. 1	1726	4	14	25	32
	Alt. 1B	1726	4	9	9	25
	Alt. 2	1723	2	3	12	25
	Alt. 3	1723	2	3	5	5
Watauga	No Action	1952	10	18	23	25
	Alt. 1	1955	4	16	24	27
	Alt. 1B	1955	5	10	10	21
	Alt. 2	1955	2	3	15	24
	Alt. 3	1955	2	3	6	6

Figure 10

COMPARISON OF LAKE LEVEL ALTERNATIVES





Target levels: The Memorial Day target elevation can generally be achieved in 90 percent of the years of record for all alternatives, as the 90-percent curves in figure 10 show. Reaching these levels, however, cannot be guaranteed in all years or for the duration of the recreation target level period of any particular year. Natural variation in rainfall makes it impossible to achieve recreation target levels at all times, regardless of power demands. The only objectives placed ahead of meeting these recreation target levels were minimum flows for navigation, the proposed minimum flows for water quality, and critical power supply situations; removing these constraints would not significantly improve the probability of achieving the target levels.

Analyses conducted for this study show, for example, that it would have been impossible to achieve the target levels in six of the last 87 years (the available historical record). Half of those six years were 1985, 1986, and 1988, three years of the recent drought. In this situation, target levels for recreation would have to be lowered consistent with available rainfall. Two types of target levels--flat and sloping--were evaluated in this study for recreation pools beyond Memorial Day, as shown in table 22. Flat recreation target levels, which remain constant over time during the recreation target period, were determined by TVA staff based on three factors: increase in summer lake area, the probability of achieving the target in a dry year, and potential increase in lake use. These target levels significantly limit drawdown for hydrogeneration. Sloping recreation target levels, which decrease with time during the recreation target level period, were developed to permit greater hydropower generation during the target level period while still providing increased recreation benefits. Both flat and sloping targets represent levels TVA would try to achieve and, when possible, exceed.

Flat target levels were chosen to evaluate alternatives 2 and 3 because these levels would maximize the expected lake levels and resulting recreation benefits. Sloping target levels were used to evaluate alternatives 1 and 1A through 1D. Using sloping target levels for these alternatives did not significantly affect the expected lake levels or resulting recreation benefits compared to flat targets because the difference between sloping and flat target levels is minimal around August 1 (when unrestricted drawdown on most lakes would begin under these alternatives). Table 21, figure 10 and Appendix B show the effect of sloping target levels for alternatives 1A through 1D. Sloping targets reduce drawdown during August and September compared to current operations, but not as much as flat targets.

Critical power system needs: As discussed in Chapter 2, the TVA power system was designed and initially operated as mostly a hydropower system. As it has been expanded, the system has been modified to take advantage of the versatility and dependability of hydropower. As other generating sources were added, their operation was planned to be primarily base load (i.e., constant operation). Hydropower is used for meeting short-term and real-time operating needs. These critical power system needs for flexibility--which hydropower is ideally suited to meet because of its versatility and dependability--must be recognized in implementing recreation target levels.

The amount of generating resources needed for power system flexibility will grow with TVA's load, but flexible generating resources are increasingly in short supply. Hydropower is limited by existing hydroturbine capacities and

Table 22
Flat and Sloping Recreation Target Levels

	Flat	Sloping				
	June–October	June 1	July 15	Aug. 1	Sept. 1	Oct. 1
Reservoir	Level (ft)	Level (ft)	Level (ft)	Level (ft)	Level (ft)	Level (ft)
Norris	1008	1012	1012	1010	1007	1007
Cherokee	1062.5	1061	1061	1060	1057	1057
So. Holston	1719.5	1723	1723	1721	1717	1717
Watauga	1948	1950	1950	1949	1945	1945
Douglas	987.5	992	992	990	985	985
Fontana	1689	1696	1696	1693	1686	1686
Blue Ridge	1683	1685	1685	1682	1679	1679
Hiwassee	1515	1517	1517	1515	1511	1511
Nottely	1771	1772	1772	1770	1768	1768
Chatuge	1923	1924	1924	1923	1922	1922

is uncertain from year to year because of variations in rainfall. Purchases of power from interconnected power systems provide flexibility, but the supply of this interchange power is decreasing as the region moves toward tighter power supply conditions. Adding nuclear units is not a solution for flexibility since nuclear units are base load plants; they cannot change their power output very quickly to meet changing load conditions. In fact, as nuclear units are put into operation, the need for flexibility increases to assure power system reliability if one of these large units is suddenly lost from service.

To assure that hydropower is still available as a resource to meet critical power system needs, the following approach would be used under the lake level alternatives. Hydrogeneration would be limited to that needed to provide minimum flows when lake levels fall below recreation target levels due to low rainfall or high power demand. Under these conditions (which would occur in only 10 percent of the years, as discussed above), extra generation would be permitted only to prevent running combustion turbines or dropping interruptible loads, and to provide frequency regulation and transmission reliability. Before extra generation can be committed, TVA's Raccoon Mountain Pumped Storage plant and all available thermal generating units would be fully committed, and all available equivalently priced interchange power would be purchased.

After these conditions are met, extra hydropower would be generated, principally from mainstream reservoirs because over half of TVA hydropower capacity is located at these dams (see table 3). This would affect mainstream lake levels, but not significantly. Reductions would be small--usually no more than one foot, which is not enough to impair commercial navigation or recreational boating significantly--and temporary. This is because such conditions usually occur in the span of a few hours during days of high power demand and tight power supplies. Mainstream lakes then would be refilled by releases from tributary reservoirs and by rainfall and runoff.

TVA, like other utilities, plans to have enough capacity to limit the frequency with which these conditions occur. Thus, the expected improvements in lake levels for each of the alternatives, shown in figure 10 and Appendix B, would not be affected significantly by this approach. Moreover, as noted above, this approach is necessary only in those 10 percent of the years when runoff is insufficient to keep lake levels above recreation targets and when power demand is high, thus limiting hydropower generation to that needed to provide minimum flows.

Other effects: Table 23 shows the effects of the lake level alternatives on the average summer and fall surface area of each of the ten reservoirs. Because of the natural topography of each of the reservoirs, some reservoirs gain more area with increased summer lake levels than others. Nottely, Cherokee, Norris, and Douglas reservoirs have the greatest percentage increase, while South Holston and Watauga have the smallest.

Figures 11-A through 14-B show how holding tributary reservoirs at higher levels would affect Tennessee River flow at two key locations: at Kentucky Dam (at the mouth of the river) and at Chickamauga Dam (at the juncture between the eastern and western half of the Valley). The combined flow of the Tennessee and Cumberland rivers is shown in figures 11 and 13 because Kentucky

Table 23
Effects of Lake Level Alternatives on Average Summer and Fall Lake Area

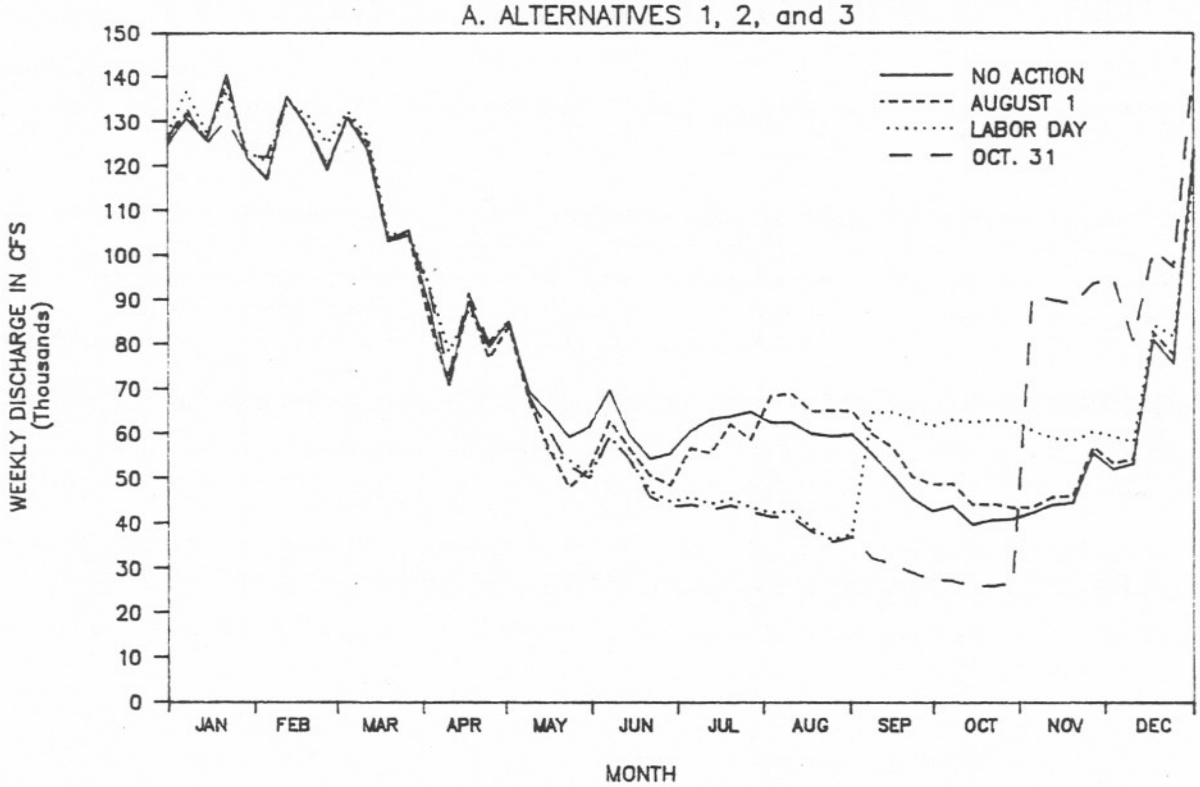
Reservoir	Current Average Summer Area (1000 acres)	Increase in Summer Area				Current Average Fall Area (1000 acres)	Increase in Fall Area			
		Alt. 1 (%)	Alt. 1A-D (%)	Alt. 2 (%)	Alt. 3 (%)		Alt. 1 (%)	Alt. 1A-D (%)	Alt. 2 (%)	Alt. 3 (%)
Norris	28.1	8	10[1]	16	16	21.7	2	26[1]	23	47
Cherokee	22.4	14	15[1]	21	21	17.5	6	30[1]	38	62
South Holston	6.9	3	4[2]	2	2	5.8	6	16[2]	8	16
Watauga	5.8	4	4[2]	6	6	5.3	2	9[2]	7	13
Douglas	24.6	8	9[1]	16	16	17.2	6	36[1]	36	61
Fontana	8.9	9	10[3]	11	11	7.4	5	20[3]	22	34
Blue Ridge	3.1	2	3[4]	6	6	2.5	3	13[4]	17	27
Hiwassee	5.3	4	4[4]	7	7	4.4	4	15[4]	18	28
Nottely	3.1	10	13[4]	23	23	2.4	6	25[4]	34	35
Chatuge	6.0	5	7[4]	9	9	5.1	3	16[4]	14	28

Notes:

1. Increase would occur only under alternative 1A.
2. Increase would occur only under alternative 1B.
3. Increase would occur only under alternative 1C.
4. Increase would occur only under alternative 1D.

Figure 11

MEDIAN FLOW FOR LAKE LEVEL ALTERNATIVES KENTUCKY/BARKLEY COMBINED RELEASES



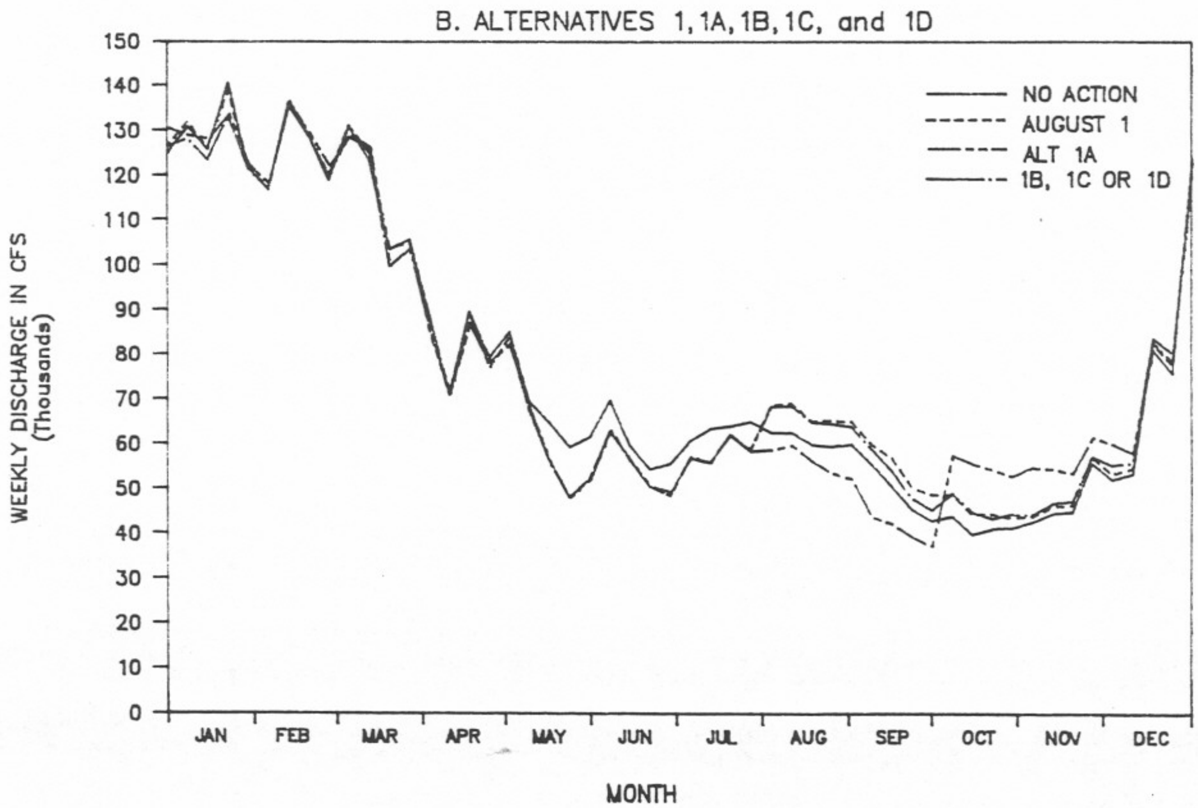
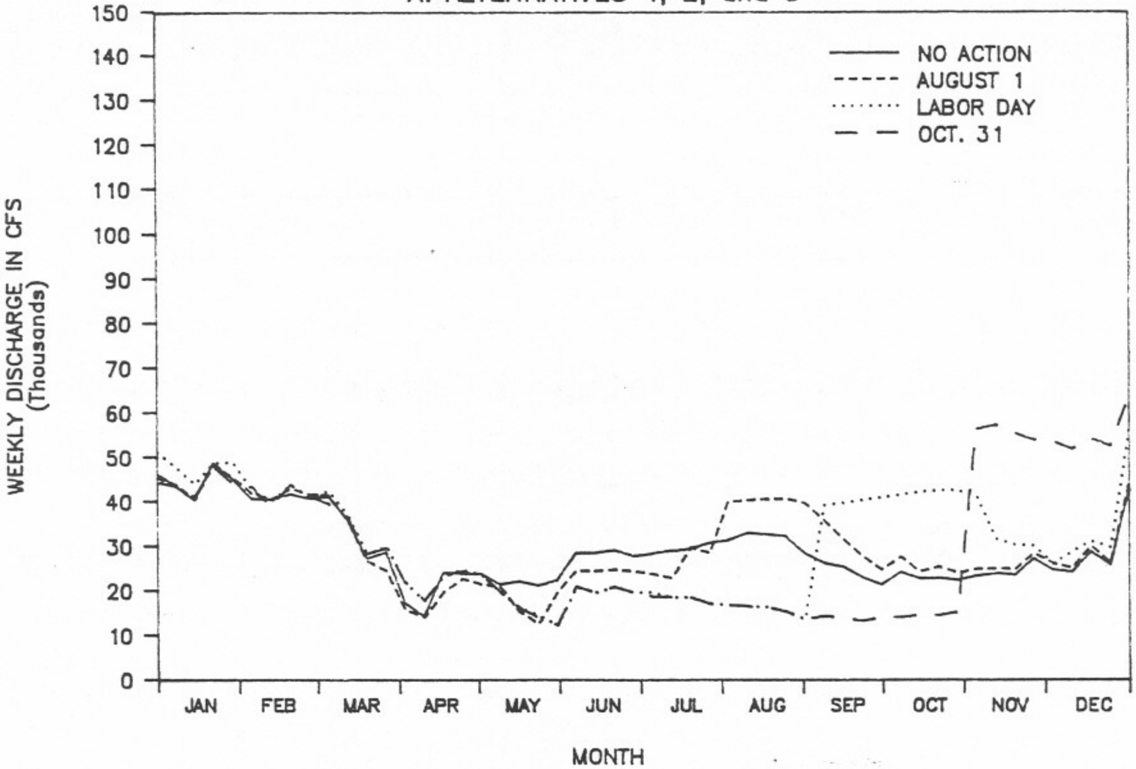


Figure 12

MEDIAN FLOW FOR LAKE LEVEL ALTERNATIVES CHICKAMAUGA RELEASES

A. ALTERNATIVES 1, 2, and 3



B. ALTERNATIVES 1, 1A, 1B, 1C, and 1D

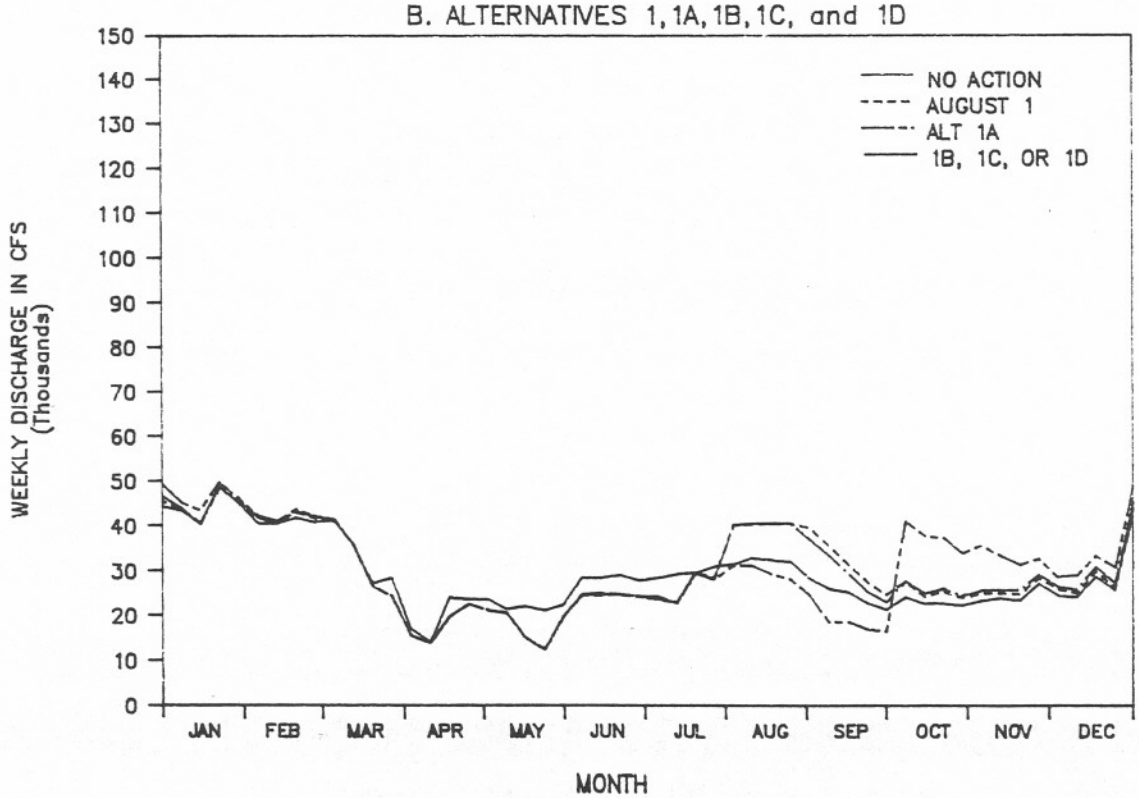
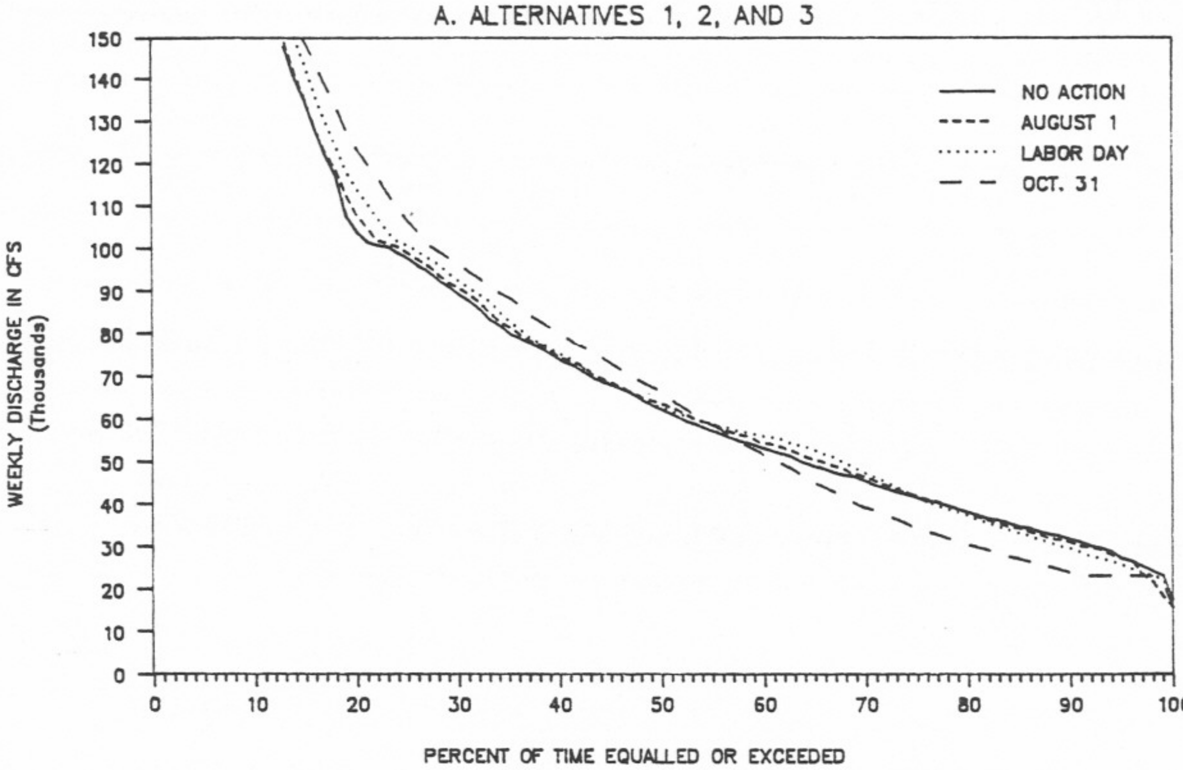


Figure 13

DURATION OF FLOWS FOR LAKE LEVEL ALTERNATIVES
KENTUCKY/BARKLEY COMBINED RELEASES



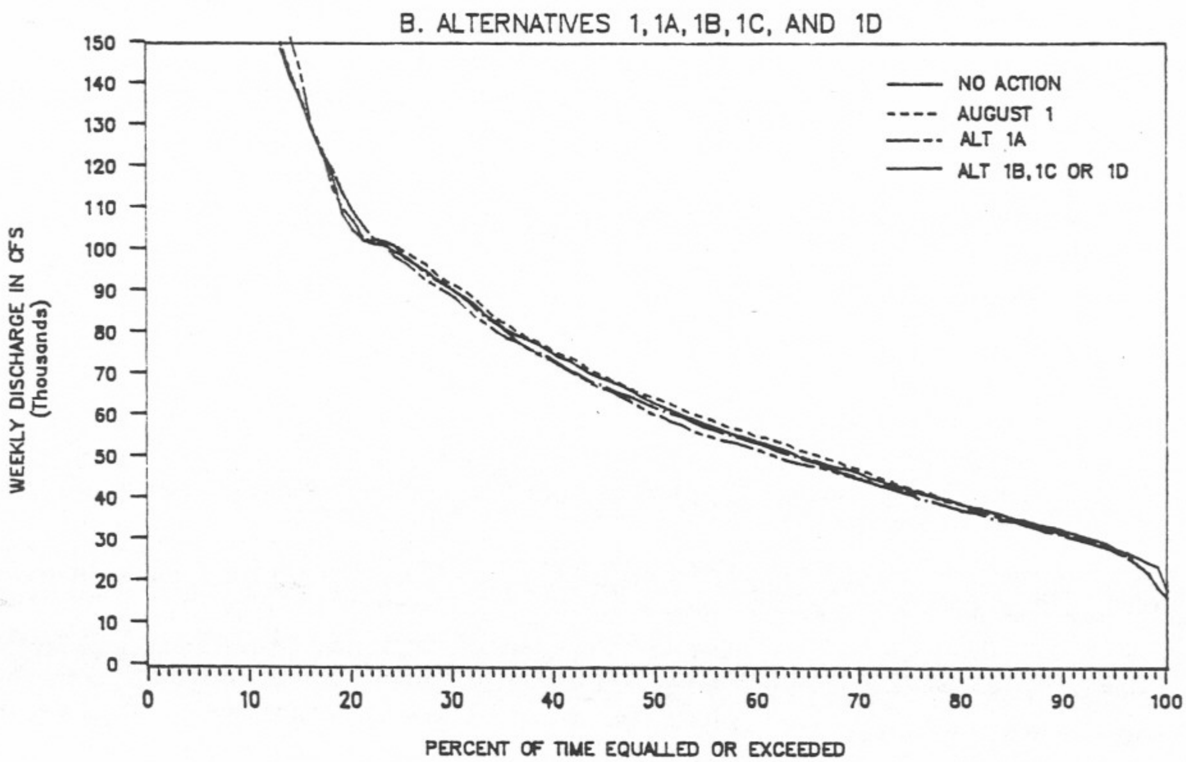
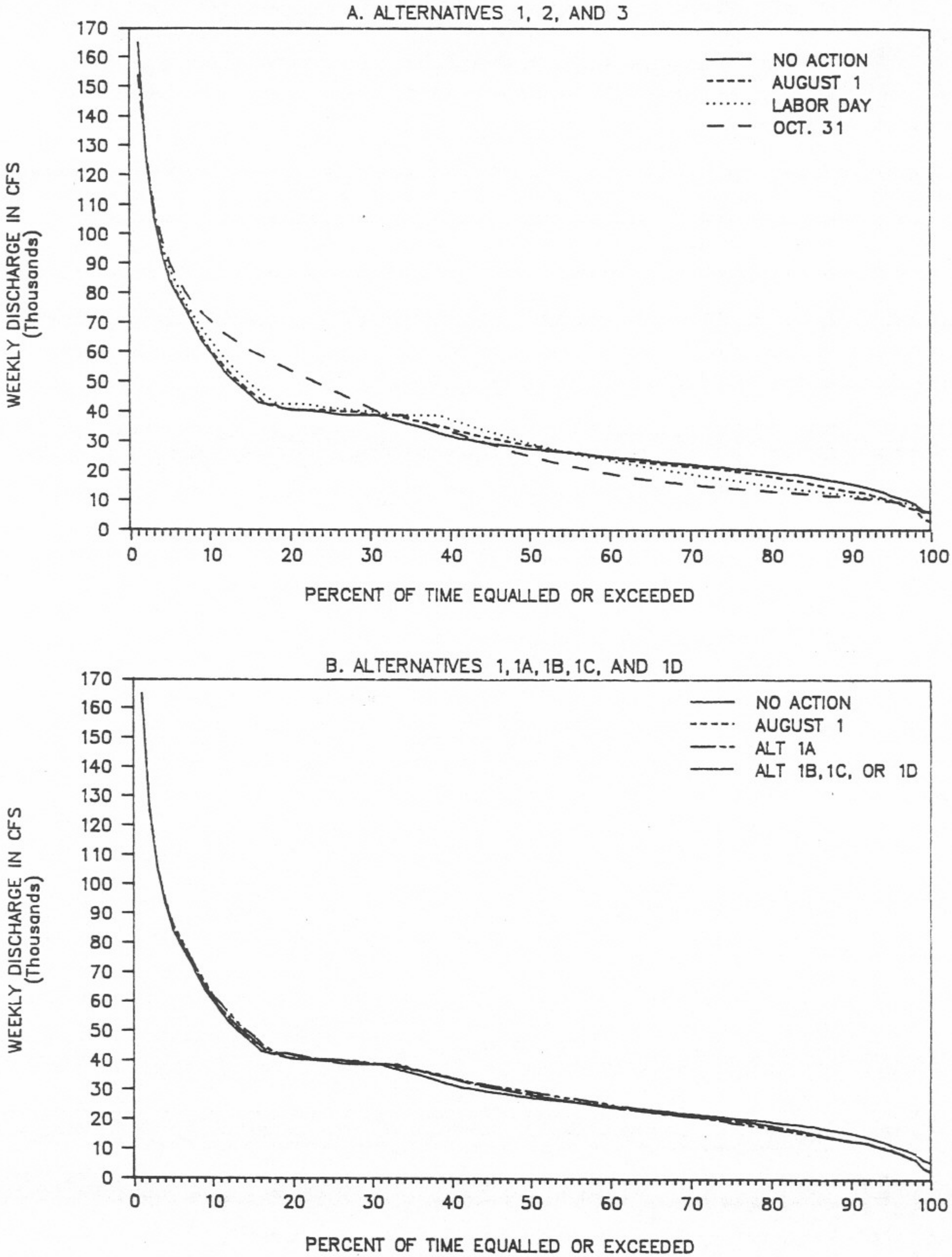


Figure 14

DURATION OF FLOWS FOR LAKE LEVEL ALTERNATIVES CHICKAMAUGA RELEASES



and Barkley reservoirs are linked by a canal such that any change in flow from the Tennessee River could be reflected in differences in releases from either dam. To capture the effect of the lake level alternatives, the flows from both dams are plotted.

These figures show that Tennessee River flow would be reduced beginning in mid-March, when rapid filling of tributary reservoirs would begin, through the end of the recreation target level period under each alternative. Low flows would occur more often under the alternatives, but minimum flow requirements would prevent occurrences of extremely low flow events. When unrestricted drawdown of the tributary reservoirs begins, average flow would be increased significantly for each of the alternatives as compared to the no action alternative. This increased flow would continue until the beginning of the winter flood control season on January 1.

The lake level alternatives do not include changes in operations at any other dams on the Cumberland River upstream of Barkley. TVA receives a portion of the hydropower produced by these dams under arrangements with the Southeastern Power Administration and the U.S. Army Corps of Engineers. No changes in these arrangements are assumed in the alternatives.

Alternatives Not Evaluated in Detail

Higher Minimum Flows From Tributary Dams. The U.S. Fish and Wildlife Service has developed techniques for calculating minimum flows for streams in other regions of the country to enhance aquatic life. The minimum flows in table 24 were calculated using a method conceptually similar to the New England Flow Method developed by the U.S. Fish and Wildlife Service for streams in the New England area. The method is adapted specifically for the Tennessee River Valley based on the median flow during dry periods under unregulated flow conditions (i.e., as if there were no dams). The objective of both the New England method and the similar method adapted to the Tennessee Valley is to calculate minimum flow requirements that protect indigenous aquatic organisms from environmental stresses greater than those that would occur under average dry conditions in their natural environment.

The minimum flows in table 24 were not evaluated in detail for two reasons: because they would reduce, if not preclude, potential improvements in lake recreation and because they would not produce the desired fisheries benefits. Figure 15 provides an example of the lake level effects of providing higher minimum flows. Lake levels on Cherokee reservoir would be much lower than currently experienced. The Memorial Day target levels could not be achieved any more frequently than under the no action alternative, even with aggressive filling of the reservoir in the spring. Potential improvements in lake levels shown in figure 10 also would be reduced. Similar effects would occur on other reservoirs, as shown in Appendix B. Besides conflicting with the potential to improve lake recreation, higher minimum flows would reduce opportunities for certain types of stream recreation by increasing flow velocities and stream depths.

Higher minimum flows also were not evaluated in detail because the benefits to aquatic life would not occur in proportion to increases in flow above the specified minimums. Most tailwaters downstream of TVA tributary dams support

Table 24
Minimum Flows Using Dry Period Median Flow Method

Reservoir	Dry Period Median Flow (cfs)
Tims Ford	112
Melton Hill	1,519
Norris	1,303
Cherokee	1,561
Ft. Patrick Henry	799
Boone	767
South Holston	199
Wilbur	83
Watauga	81
Douglas	2,118
Chilhowee	1,911
Fontana	1,512
Ocoee No. 1	556
Ocoee No. 2	478
Ocoee No. 3	459
Blue Ridge	200
Apalachia	970
Hiwassee	921
Nottely	183
Chatuge	158

"put, grow, and take" trout fisheries that would not otherwise exist in these areas. The dams create an artificial cold water habitat that is inconsistent with sustaining natural resident or seasonal warm water fisheries, regardless of flow rates.

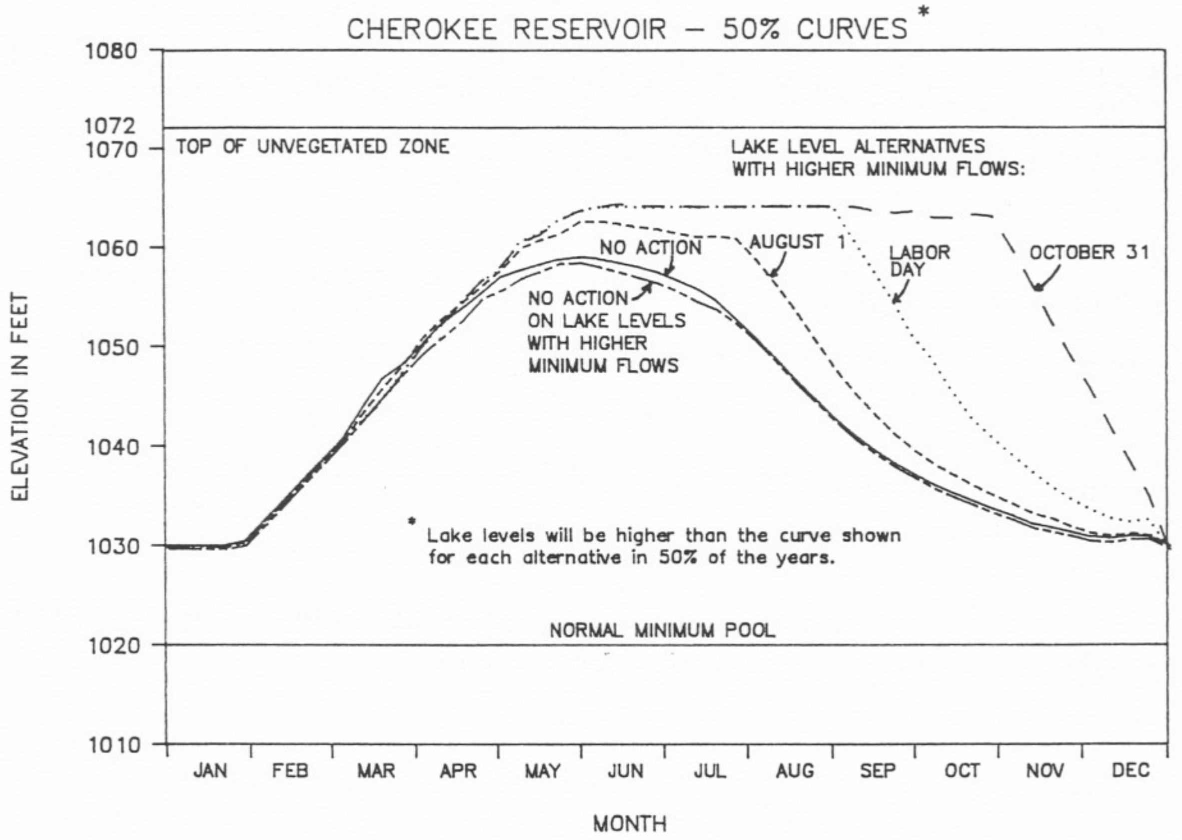
The minimum flows evaluated in the alternatives were developed to allow for multipurpose use of tributary reservoirs and tailwaters. Chapter 6 contains a recommendation to continue case-by-case evaluation of tributary tailwaters by TVA, state and federal agencies, and other interest groups, to enhance aquatic life and other uses of the tailwaters.

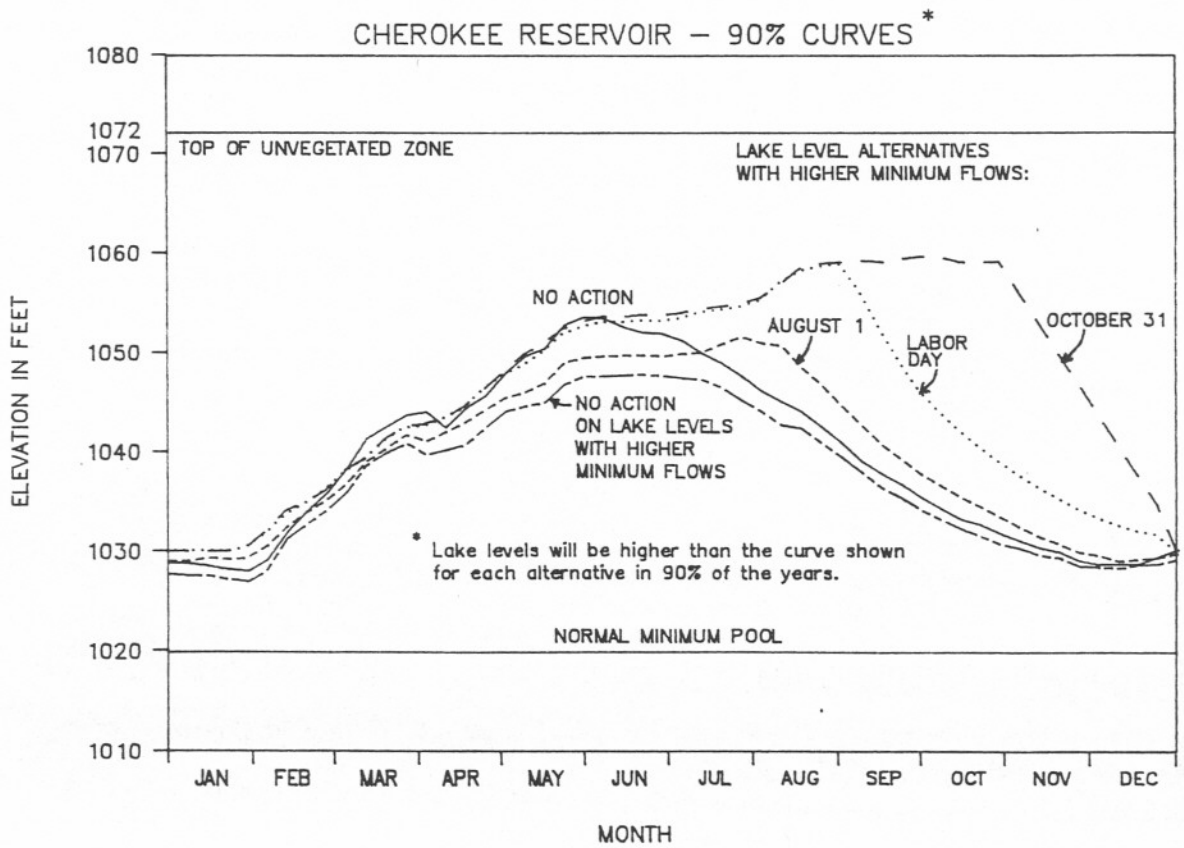
Raising Winter Levels in Mainstream Reservoirs. Technological improvements have dramatically changed shipping on the Tennessee River. In the 1930s, 800-horsepower towboats and 26-by-175-foot barges were standard equipment; today, 3000-horsepower towboats push 35-by-195-foot jumbo barges. These faster, heavier barges, however, run a higher risk of scraping bottom if they do not reduce speed, or running aground if they stray from the dredged navigation channel in the tailwater of most mainstream dams. The problem seems to be the worst in the tailwater reaches below Pickwick, Nickajack, Chickamauga, Watts Bar, and Fort Loudoun dams. In addition, some ports have marginal operating depths in winter months.

During normal and wet winters, these problems are not significant because river flows and water depths in tailwater areas are high. However, the drought conditions experienced in recent years resulted in lower average flows from turbines and spillways during winter months. Reduced tailwater levels, in turn, contributed to an increase in channel accidents and port delays.

Figure 15

EFFECT OF HIGHER MINIMUM FLOWS





As a result, navigation interests have proposed raising winter minimum pools up to three feet on mainstream reservoirs. This proposal has not been fully evaluated in this study because, first, the potential impact on flood protection appears to far exceed the benefits to shippers and, second, there are other remedies available.

Raising winter minimum pools up to three feet on mainstream reservoirs primarily would benefit tailwater areas during winter months when water depths are lowest. This would save commercial navigation interests up to $3 million annually primarily in reduced delays and also in avoided cleanups after accidents. In contrast, the increased annual costs in terms of flood damage would be as much as $10 million, over three times higher. The annual benefits and costs for a smaller increase in navigational depth would be less, but the ratio of costs to benefits would not be expected to change greatly.

Over 80 percent of the $10 million average annual flood loss would occur at Chattanooga. This is because the value of winter flood storage in Chickamauga, Watts Bar, and Fort Loudoun dams is much higher than other mainstream reservoirs. These reservoirs provide the only storage available for flood-producing rains that fall in the eastern Valley downstream of the major tributary reservoirs. Flood damages that occurred in 1973 and 1984 in Chattanooga when heavy rain fell in this area occurred in part because of the limited flood storage in these three reservoirs.

Other solutions to the problems experienced by commercial navigation include reducing tow speeds, reducing barge loads, and more frequent servicing of channel buoys in tailwater areas by the U.S. Coast Guard. These measures can be effective especially during drought conditions when the problems experienced by towboat companies in tailwater areas are more frequent. Dredging offers another alternative to raising winter minimum pools in port areas. However, correcting depth problems by dredging at six critical ports would cost from $12 to $15 million, with an annual benefit of about $2 million.

While the proposal to raise winter levels in mainstream reservoirs was not accepted, other suggestions to improve navigation prompted a review of TVA's role in developing the navigation potential of the Tennessee River. This review resulted in a recommendation, presented in Chapter 6, for increased TVA support for navigation development in the 1990s.

<u>Raising Winter Levels in Tributary Reservoirs.</u> Lake recreation interests proposed raising winter minimum and/or flood guide levels on tributary reservoirs to increase the chance of filling the reservoirs each spring; to promote lake recreation and tourism development; and to reduce the operating costs of boat dock and marina operators who must move their floating facilities several times a year because of the deep annual drawdown.

TVA responded to this same request in 1971 by reevaluating flood control needs. As a result of that study, TVA was able to raise normal minimum levels (see figure 7) an average of about 50 feet on nine tributary reservoirs--some as much as 100 feet. Flood guide levels were raised during the month of January an average of about six feet on eight reservoirs, the greatest increase being 10 feet. No change was made in flood guide levels for any other month. The relatively small change in flood guides was accomplished without a significant sacrifice in flood control capability. The significant increase in normal minimum levels provided a smaller zone of operating flexibility for hydropower production in the winter months under normal conditions. Water stored below the normal minimum levels can be used during droughts and power emergencies, or for maintenance purposes, with TVA Board approval.

From a system-wide perspective, the changes made in 1971 to increase recreation benefits on tributary reservoirs effectively used up the flexibility that then existed in winter operations of the reservoir system. Further large decreases in winter flood detention capacity would be required to increase significantly the benefits to commercial recreation or tourism interests on tributary lakes. However, such changes would have major effects on flood control benefits and would greatly reduce the flexibility of hydropower operations during the winter months.

Providing flat reservoir pools year round clearly would involve an unacceptable flood risk. This, in effect, would remove all flood storage capacity from tributary reservoirs and would be tantamount to exposing the city of Chattanooga to the same flood risk that it experienced before construction of the TVA reservoir system. Adjusting the normal minimum pools and flood guide curves on all tributary reservoirs upward to the maximum extent allowable within the constraints of TVA nuclear plant licenses and dam safety guidelines would double the chance of major floods in Chattanooga--a change that most decision makers probably would find unacceptable.

However, changing the flood guide curves and/or normal minimums on some lakes and not on others, or changing them on all lakes to a much lesser extent, may be acceptable from a Chattanooga flood risk perspective. In the case of individual reservoirs, this has been implemented at Fontana and is being evaluated for Norris as part of TVA's ongoing effort to maximize reservoir system benefits within the framework of existing policies. These marginal changes are being evaluated and can be implemented under current TVA policy.

Construction of Levees at Chattanooga. As mentioned in Chapter 1, the original design of the flood control system for the eastern half of the Valley called for the city of Chattanooga to construct a system of levees to provide additional protection against damage from extreme floods. Except for partial installation of levees along South Chickamauga Creek, this levee system was never built. Instead, local government in Chattanooga and area residents have assumed the risk of flood damages that cannot be prevented by TVA flood control operations. Land that is subject to flooding has been identified, and property owners can purchase flood insurance if eligible.

If the city of Chattanooga decided to build levees to reduce or eliminate the risk of local flooding, TVA might operate the reservoir system differently in a particular flood situation. However, the amount of storage space in reservoirs upstream of Chattanooga that currently is reserved for flood control would not change.

TVA could consider raising these levees even further, if they were built, to reduce the amount of flood storage needed upstream, thereby raising winter levels in tributary reservoirs. However, this alternative was not considered because it would be very expensive, it probably would have significant adverse environmental effects, and it is predicated on the unlikely possibility that Chattanooga would construct levees.

More Stable Reservoir Levels During Spring Months. Fishing enthusiasts and state fishery management agencies want stable lake levels during periods in the spring when water temperatures are in the critical range for successful spawning of targeted fish species. Although other factors are involved, eliminating drawdowns and permitting only gradual increases in water level (half a foot per day) would increase the chance of reproductive success.

Reservoir operations to stabilize lake levels during the fish spawning season are conducted under TVA's current policy, as noted in Chapter 2. Flood control operations take priority, however, and can cause rapid changes in pool levels. This constraint, combined with factors beyond human control such as storms and changes in levels due to turbine operation, make it difficult to provide more stability for spawning than TVA already provides.

Reservoir operating alternatives which place greater priority on attaining recreational summer pool levels (discussed in detail earlier in this chapter) could result in more increases in pool levels during fish spawning. However, these increases should not affect, and may even benefit, reproductive success. Decreases in pool levels which are detrimental to spawning would be less likely.

Changes to Summer Pool Levels on Mainstream Reservoirs. Some recreation and fishing interests proposed changes to summer pool levels in mainstream reservoirs--in some cases, increases to improve access; in other cases, decreases to manipulate fishery habitat. Significant changes in recreation benefits arising from such changes are unlikely because annual and summer drawdown on these reservoirs is relatively small.

Eliminating Summer Level Fluctuations in Mainstream Reservoirs. Weekly, one-foot fluctuations during the summer and early fall months disrupt mosquito habitat on mainstream reservoirs, thereby controlling mosquito larvae during the peak of the mosquito breeding season. If these fluctuations were discontinued, the risk of disease would not increase significantly, but mosquito populations would grow. When drought conditions prevented mosquito control fluctuations during the summer of 1988, the number of complaints about mosquitos increased dramatically. Lake users and communities along the reservoirs are accustomed to a relatively high level of mosquito control, and would react negatively to reduced control.

Chemical spraying offers an alternative method of mosquito control, but the cost would be much higher and pool level fluctuation is more acceptable from an environmental perspective.

Emptying Individual Reservoirs Every Decade. Several objectives were cited by advocates of this special fisheries management operation: to grow vegetation in the lake bottom for cover after filling, to reduce existing fish stocks and replace them after filling with a more desirable mix of species, and to improve water quality. Added advantages would result if such an operation could be used in conjunction with draws for dam safety inspections and maintenance.

Emptying individual reservoirs each decade is impractical, however, because recovery of pool levels could take longer than a year and lake recreation and hydropower generation would be disrupted for an extended period. In some reservoirs, water supplies also would be greatly impacted. Moreover, there are more practical ways to achieve some of the objectives--installing fish attractors and controlling pollution, for example.

Aquatic Vegetation Management. TVA continually evaluates its methods and practices for managing aquatic vegetation and periodically seeks public input during these evaluations. In the near future, TVA intends to supplement the EIS which it issued for its aquatic plant management activities. As part of this review process, alternatives to current methods and practices will be considered and public comment sought. The conflicts among boaters, shoreline property owners, fishing enthusiasts, and state fishery management agencies over the appropriate degree of aquatic vegetation management on individual reservoirs also will be addressed.

Purchasing More Land for Reservoir-Related Uses. Some groups foresee a need to reserve more land along the river and reservoir system to meet future needs for wildlife habitat, recreation, navigation ports, and economic development. They proposed that TVA retain the relatively small amount of reservoir land it already owns above the maximum shoreline contour, and purchase and inventory more land for these purposes.

This proposal was not evaluated fully because a need for a major land acquisition program has not been established, and because Congressional funding for such a program is unlikely at a time when federal budget constraints make it difficult to fund necessary reservoir maintenance work and other stewardship activities. In addition, purchasing significant amounts of land would probably meet with considerable public and political resistance.

Acquiring key tracts of land to help meet specific needs under a "willing seller" approach may be appropriate. However, subject to the availability of funds, this can be accomplished under existing TVA policies.

Purchasing Flowage Easements on Flood-Prone Lands. Some landowners along TVA reservoirs want TVA to purchase flowage easements from them because their land is inundated during major floods on the Tennessee River. Usually, these lands are in the headwaters of a mainstream reservoir, and the property owners are farmers who plant fall and winter crops on land that is subject to flooding even under natural conditions. This alternative was not considered because TVA flood control operations have not increased the occurrence of flooding on these lands; purchasing the easements would amount to a federal subsidy of these landowners.

When each reservoir was constructed, TVA purchased easements on land where increased flooding due to TVA activities was expected. Backwater profiles (the water level during floods) for both pre-dam and post-dam conditions were compared, and easements were purchased on land where the post-dam or regulated backwater profile was higher. Flooding still occurs above the elevation where easements were purchased, but no more (and usually less) often than would occur naturally. Many of the landowners who request easements are new landowners who are unaware of the history of flooding prior to TVA.

Aside from not being responsible for the problem, it is impractical for TVA to consider purchasing easements on these naturally flood-prone lands simply to reduce flood damages to crops. For example, the cost of easements on the upper reaches of Kentucky Lake, where these requests are frequently made, would be very high ($50 to $70 million). Even if additional easements were purchased, damages would continue unless farmers stop farming these lands. Local governments could institute land use controls to prevent farming, but this is unlikely.

Improving Lake Access Areas. Some lake users would like to see improved public access to TVA tributary lakes, including better maintenance and new facilities at existing access areas and development of additional access points. Toward this end, it was proposed that TVA assume full responsibility for public access to TVA lakes. Private developers of lake access areas would likely oppose this action. TVA's policy is aimed instead at encouraging the private sector and other public agencies that manage lands around TVA lakes to develop appropriate recreation facilities, including lake access sites. TVA supplements these efforts by providing basic recreation facilities on selected TVA lands to help meet public needs.

This proposal also was not fully evaluated in this study because the cost would be prohibitive. Many public access areas on tributary lakes are not controlled by TVA. To assume control of these areas and upgrade facilities where necessary, and to provide additional access areas where access currently is inadequate, would cost about $9 million. (This cost includes upgrading existing campgrounds, day use areas, and boat ramps, including those already controlled by TVA; it does not include acquiring or making improvements at state parks.) Annual maintenance costs could be as high as $1 million.

Strengthening TVA's Authority to Control Activities that Adversely Affect Reservoir Uses. Because of TVA's conspicuous role in regulating flow for navigation, flood control, and hydropower purposes, the general public holds TVA largely responsible for the condition of the Tennessee River system. Hence, TVA bears the brunt of public criticism even in such areas as recreation and water quality where it has only indirect control.

Three suggestions were made to improve this situation: expanding TVA's regulatory authority, using the doctrine of riparian water rights to control pollution, and utilizing deed provisions on lands TVA has transferred to control activities affecting water quality. These suggestions were judged infeasible or ineffective, however, and were not evaluated in detail for the reasons discussed below.

More regulatory authority: Suggestions for giving TVA more regulatory authority--to enforce laws, control pollution, and zone private lands around reservoirs, for example--indicate confusion about the roles of TVA and state and local governments. They were not given serious consideration because it is very unlikely that the levels of government that now have authority in these areas would support legislation providing such authority to TVA.

Others urged TVA to use its Section 26a authority to help control pollution. Section 26a jurisdiction is limited to the approval of plans of dams, associated structures, or other obstructions, affecting navigation, flood control, or public lands or reservations. TVA may not, as part of its review of a Section 26a application, impose more stringent effluent limitation requirements than those required by federal or state regulatory agencies. However, in issuing approvals pursuant to Section 26a, TVA does require the use of best management practices to help reduce pollution from nonpoint sources.

Aside from the limited scope of Section 26a authority, this alternative was not evaluated in detail because up to 80 percent of the pollution comes from lands and activities that are not subject to Section 26a jurisdiction. Table 14 in Chapter 3 shows that TVA granted only 33 permits under Section 26a from 1984 to 1988 for industrial uses. This number is far less than the number of discharge permits granted in the Tennessee River watershed by the seven Valley states during the same period.

Chapter 3 also shows that some 8600 Section 26a approvals were granted for residential shoreline structures in the same five-year period under TVA's policy governing development of the marginal strip of land around reservoirs. The recommendation in Chapter 6 to include marginal strip land in TVA's reservoir land management planning process could help control the destruction of natural habitat and subsequent erosion of shorelands that can accompany such development.

Riparian water rights: The possibility of using the doctrine of riparian water rights to control pollution sources on the river and reservoir system has been considered by TVA previously. This doctrine, recognized in all the Valley states, is a real property right associated with the ownership of riparian lands (lands through which waters flow) to which the U.S. and TVA (like other owners of riparian land) are entitled. It allows an owner to make reasonable use of riparian waters, while recognizing that all other riparian owners have similar rights of reasonable use. A legal action based upon the riparian rights doctrine to enjoin and recover damages for interfering with a riparian owner's right of reasonable use must be pursued in the courts.

To prevail in such an action, TVA would have to show that the upstream use is unreasonable. The riparian rights doctrine permits some pollution of adjoining waters as a reasonable use; reported cases show that ordinary farm and domestic use will not support a claim for damages. A large portion of the pollution load to TVA reservoirs is from nonpoint sources that arise from such ordinary uses. In addition, releases from point sources that are operating under a valid state discharge permit would likely be considered reasonable uses. TVA also would have to show that its ability to reasonably use riparian waters had been impaired. Some cases have permitted a riparian owner to enjoin unreasonable upstream uses that reduce potential uses, but no damages can be collected.

Even if TVA could show that an unreasonable use had occurred which caused injury to TVA, the measure of recoverable damages would not necessarily be TVA's cost to increase DO to a particular level, but rather the legal measure of the unreasonable impairment of TVA's water use. Also, TVA would have to pursue legal remedies on a massive scale to collect damages; each polluter and its contribution to TVA's injury would have to be determined. The cost of the lawsuit could easily exceed the damages recovered.

Deed provisions on transferred lands: In transferring lands it once owned, TVA inserted various provisions in the respective deeds giving it certain rights (but not the obligation) to control activities on the land having an effect on water quality. It is not necessary to invoke these provisions for point source discharges because state and federal pollution control requirements are generally adequate. However, in some instances, enforcing these deed provisions can be the only available means of abating nonpoint source pollution. This approach was not fully evaluated on a system-wide basis because the amount of land with such deed provisions along TVA reservoirs is small. Also, case-by-case actions can be taken under existing policy.

Normandy and Columbia Reservoirs. In 1970, Congress directed TVA to build Normandy and Columbia dams on the Duck River in south central Tennessee. The purposes of the Duck River Project were flood control at Shelbyville, Columbia, and Centerville, Tennessee, as well as on the lower Tennessee, Ohio and Mississippi Rivers; water supply for a five-county region around the reservoirs; water quality control on the Duck River downstream from Shelbyville and Columbia; recreation on the two lakes; and the economic growth resulting from these benefits.

Normandy Dam was closed in 1976, providing flood protection benefits for Shelbyville, water supply for four of the five counties, flows for water quality control downstream from Shelbyville and Columbia, and recreation benefits on Normandy Lake. Construction of the proposed Columbia Dam and reservoir was halted in 1980 when it was determined that the project, as planned, was likely to jeopardize the continued existence of two federally listed endangered species.

In the face of the delay of Columbia Dam, residents and community leaders in the area of the Duck River Project have requested changes in the operation of Normandy reservoir to obtain greater water supply and recreation benefits. Because the original plan was to operate both Normandy and Columbia dams together to achieve the desired objectives, and no decision has been made to change this plan, these alternatives have not been considered in this study. These and other alternatives can be evaluated by TVA in concert with local residents and community leaders in the context of the Duck River Project.

Normandy reservoir is eutrophic, meaning "biologically productive" with an abundance of life-supporting nutrients. These nutrients, originating principally from nonpoint source pollution, natural high phosphorus rock, and municipal discharges flowing into Normandy, promote rapid growths of algae, which cause taste, color, and odor problems in the drinking water drawn from the reservoir. Improving these conditions means reducing nonpoint sources of pollution, which is the responsibility of state and local governments. Color problems are related to dissolved iron and manganese in the water in the lower depths of the reservoir and, at a minimum, are aggravated by nonpoint source pollution. TVA is planning to provide technical assistance to help alleviate these problems. Chapter 6 contains recommendations for TVA cooperation with the states to help achieve water quality and other goals.

Energy and Water Conservation. Some environmental groups proposed that energy and water conservation alternatives be considered in this study. Energy conservation alternatives are an important consideration to TVA's power system as a way of reducing the need for more expensive forms of generation; however, they are not relevant to this review of hydropower's role in the operation of the reservoir system. Although important because of its unique operating attributes, hydropower is a relatively small component of the TVA power system--about 10 to 15 percent of total system capacity. Also, as long as it is the cheapest energy source available, hydropower generation always will be used fully to avoid using higher cost resources.

Water conservation alternatives are of interest to some municipalities and utility districts as a means of reducing costs and limiting the need for capital investments in system expansions. However, as discussed in Chapter 3, most areas in the Tennessee Valley enjoy a dependable water supply. Very little of the water flowing through the Tennessee River system is put to consumptive use (discharged to the atmosphere, transferred to another river basin, or taken up in plants, rather than returned to surface and groundwater sources), and consumptive uses are not expected to increase significantly.

Water supply quality is not a widespread problem. However, in some parts of the Valley, the available water may require special treatment for water supply use and may not always be acceptable for drinking and assimilation of industrial and municipal wastes. Reservoir release policy alternatives and recommendations concerning TVA and state cooperation on water resource issues, discussed in subsequent chapters, relate to this concern.

Chapter 5

ENVIRONMENTAL AND SOCIOECONOMIC CONSEQUENCES

This chapter describes the environmental and socioeconomic effects associated with the reservoir release and lake level policy alternatives evaluated in this study. It is based on the information about current conditions presented in Chapter 3.

No Action Alternatives

There are two "no action" alternatives. One is to continue TVA's current reservoir release policies for dissolved oxygen (DO) and minimum flows; the other is to continue TVA's current lake level policies affecting tributary reservoirs. While one set of policies could be changed and the other preserved, this section combines the discussion of these alternatives. Where there are specific effects associated with no action on reservoir releases, or no action on lake levels, this is indicated.

Water Quality. *Water temperature:* The temperature regime of tributary reservoirs and tailwaters, described in Chapter 3, would not change under existing reservoir release and lake level policies. During the summer, temperature stratification in TVA reservoirs will continue to result in temperature fluctuations in tailwater areas. When turbine use is intermittent, this can cause low temperature stress to fish below some tributary dams.

Dissolved oxygen: Gradual improvements in DO concentrations are expected under existing policies. TVA and the state of Tennessee have agreed to work cooperatively to provide higher minimum flows and maintain DO levels in releases at or above a minimum level of 4 milligrams per liter (mg/l), with a long-range goal of meeting Tennessee water quality criteria for DO (5 mg/l in warm water fisheries; 6 mg/l in cold water fisheries). As part of this agreement, an effective nonpoint source control strategy is to be formulated and implemented by the state of Tennessee. Achievement of the goals of the agreement is predicated on adequate Congressional and state funding. Budget constraints are unlikely to permit rapid progress at all TVA dams in Tennessee, and dams in other states are not covered by the agreement.

Wetlands. Under present operating policies, wetland communities of TVA's reservoir system will continue to exist much as they are. Most such communities have developed within the constraints of the present system. Adverse impacts currently noted are the result of changes in land use (e.g., filling and draining).

Wildlife. The continuation of current operating policies would have no effect on existing wildlife population trends. The migratory and resident species of wildlife have adapted to present conditions, using the habitat as it is available.

Terrestrial endangered and threatened species: As noted in Chapter 3, of the terrestrial animal and plant species currently listed as endangered or threatened, there are four which are closely associated with the mainstream Tennessee River or its tributary streams and reservoirs--bald eagles, gray bats, the green pitcher plant, and Ruth's Golden Aster. None of these is placed at risk by TVA's existing reservoir operating policies. Human disturbance will continue to be the principal threat to their continued existence.

Aquatic Resources. Most plankton, benthic, and fish communities in TVA reservoirs and tributary tailwaters have responded to existing conditions and will maintain their current population levels unless the character of the streams or the watershed were to change drastically. Gradual improvement in aquatic habitat should result from the agreement between TVA and the state of Tennessee, but any effects on existing population trends are likely to be far in the future and limited to specific locations in Tennessee.

A few surviving aquatic species have not adapted to impoundment and will continue to decline under TVA's current lake level regime. At the same time, increasing commercial and sports interest in some aquatic resources is causing harvest pressures that cannot be met by current and probable future population levels. Paddlefish, sauger, and several mussel species are presently in high demand, but their population levels are suppressed by current reservoir operating policies. Other mussel species persist in remnant large-river habitats, but apparently are no longer reproducing successfully. Under present reservoir release policies, these trends will continue and the affected resources may be lost.

The probable effects of continuing existing policies on specific aquatic resources are discussed in more detail below.

Aquatic macrophytes: With continued operation of the reservoir system under present lake level policies, macrophyte populations in the main Tennessee River will continue to expand wherever suitable habitat conditions exist. Tributary reservoirs will continue to be largely free of macrophytes, principally because of the controlling effect of large seasonal changes in water level.

Benthic invertebrates (benthos): Currently, benthic diversity is limited by low dissolved oxygen (DO) acting in concert with flow alterations or no-flow conditions at some locations. Low DO has reduced species diversity. Widely fluctuating flows, often accompanied by wide fluctuations in water temperature, have reduced the amount of the most productive (riffle) habitats. Insufficient flows between turbine release periods have allowed sediment accumulation on rocky substrates and have impaired feeding and respiration of many benthic invertebrates. Gradual improvements in these conditions at certain locations in Tennessee can be expected under existing reservoir release improvement efforts, depending on the level of funding.

Mussels: The current depressed status of freshwater mussel stocks in the Tennessee River system is the result of habitat losses, habitat alteration, and continued commercial harvest. Continuing the existing reservoir release improvement efforts in Tennessee would gradually improve DO levels; however, resulting improvements in mussel habitat will be far in the future.

Fish: Under existing reservoir release improvement efforts, gradual enhancement of current tailwater fishery conditions can be expected as funding permits. However, in the near-term, fish communities will continue to experience the adverse effects noted in Chapter 3. Tributary tailwaters will continue to undergo wide fluctuations in water level, thus limiting the wetted area available to both benthos and fish. At some locations, low DO levels will continue to limit food production, available habitat, and growth of fish. Also at some locations, wide temperature fluctuations resulting from on-off operation of dam discharges will continue to limit available habitat, adversely affect fish growth, and for some species, interrupt spawning runs.

On tributary reservoirs, late spring-early summer drawdowns will continue to expose shallow spawning areas and reduce the amount of flooded terrestrial vegetation which serves as a food production and shelter area for young fish. Existing policies also will continue to affect human use of these resources by limiting access to tributary reservoirs which are subject to extreme drawdowns, and by limiting fishery management options, especially those associated with the enhancement of tailwater fisheries.

Endangered and threatened aquatic species: Continuation of existing reservoir management policies would not have a significant effect on the survival of the 17 federally listed endangered or threatened species that occur in the main Tennessee River or in tributary reservoir tailwaters. Because the present condition of these species was largely determined by impoundment of the reservoirs and reservoir release policies, existing population trends would be expected to continue.

Scenic Resources. There will be some improvement in scenic resources under existing policies. Tailwater regions will consist of a series of shallow pools and exposed riffle areas when hydro turbines are not operating, except where minimum flows are instituted under the current agreement with Tennessee. Drawdown of tributary lakes during the summer, fall, and winter months will continue to leave extensive regions of mudflats and dry coves around the perimeter of each reservoir.

Navigation. Under the no action alternative, commercial navigation benefits from TVA reservoir operation will continue at the current level. A 9-foot navigational depth will be maintained and flows at Pickwick and Kentucky dams will continue to be provided to ensure adequate depth in the tailwater.

Flood Control. There would be no change in flood risk to Chattanooga or to other cities and towns along streams under existing policies.

Hydroelectric Power. There would be no change in expected hydropower generation or its value to the residential consumer in the Tennessee Valley under existing policies. The allocation of hydropower to residential consumers has saved them an average of $300 to $350 million a year on electric bills (about $10 per month per customer) compared to the cost if the same amount of power had come from other sources. Variations in rainfall and runoff will decrease the value of hydropower to as low as $170 million during drought years, and increase it to as much as $450 million in wet years.

Thermal Generation. The no action alternative will not change the use of hydropower by the TVA power system and, hence, will not change the environmental effects of thermal generating plants operated by TVA.

Lake and Stream Recreation. Recreational use of the lake and tailwater areas of TVA's tributary dams and reservoirs will continue to increase even without a change in TVA's lake level or release policies, following the national trend of increased outdoor recreation.

Most of the increased tributary lake recreation use will occur in the late spring and early summer. This is because of changes in the character of TVA reservoirs that begin by the middle of July under existing lake level policies. By mid-summer, campsites are beginning to lose their relationship with the reservoir; beach areas are very shallow or dry; boat docks are beginning to move from their original summer locations; the distance between the water on the launching ramps and the ramp parking areas has increased; and submerged islands are getting dangerously close to the water surface, creating boating hazards. By Labor Day, recreational use has declined significantly as a result of these changes and the ending of the summer recreation season. By October 31, the reservoirs have lost one-third of their surface area, and many recreation use facilities have closed.

Most of the increased stream recreation that is expected under existing release policies will occur where access facilities are currently located or new ones are built. Public investment in stream access facilities is expected to remain low relative to public investment in lake access facilities, limiting growth in stream recreation use and preserving its character as a low density, informal use.

Population and Income. Continuing TVA's current lake level policies would not have a significant effect on existing patterns of population and income growth. On reservoirs where second-home development is contributing significantly to population and income levels (e.g., Nottely and Chatuge), existing policies will continue to be a limiting factor. This is because drawdown early in the summer exposes mudflats which make the affected portions of shoreline less attractive for development.

Land and Shoreline Development. The no action alternative is not likely to alter existing patterns of land and shoreline development. The number of shoreline structures will continue to grow as a result of growth in population and in the demand for privately owned shoreline lands for residential development. Growth pressures are expected to be greatest on Pickwick, Melton Hill, Tellico, and Fort Loudoun reservoirs on the navigable waterway; and on Chatuge and Nottely on the tributaries (see table 12). Without adequate controls on shoreline development, some areas around these high growth lakes are likely to experience continued negative impacts, including nonpoint source pollution from soil erosion, failing septic systems and user activities on developed shorelands, loss of aquatic and riparian habitat for fish and wildlife, and loss of the scenic value of forested shoreline.

Cultural Resources. Losses of archaeological sites could continue under existing reservoir operating policies. Repeated turbine startup and shutdowns, reservoir pool level fluctuations, and occasional flood flows may contribute to natural erosion of the shoreline above and below the dams. This can cause loss of sites as a result of bank slumping. In addition, as shoreline is exposed during winter drawdown, vandalism and looting can occur.

Under existing lake level conditions, archaeological sites also will continue to be threatened by increases in shoreline development and wave wash due to wind and commercial and private water craft on navigable portions of reservoirs and rivers.

Reservoir Release Policy Alternatives

Water Quality. *Water temperature:* Providing increased minimum flows during idle turbine periods will reduce the daily peak temperatures in tributary tailwater areas by about 1 to 2°C (2 to 4°F) and extend the benefits of these cooler temperatures further downstream. During periods of the year when the water temperature is warmer than the night-time air temperature, increased minimum flows also will produce 1 to 2°C (2 to 4°F) increases in minimum water temperature. In addition, increased minimum flows will tend to reduce the difference between turbine release temperature and receiving tailwater temperature, thus reducing the possibility of temperature stress on fish when the turbines are reactivated after being idle for some time.

Increases in minimum biweekly flows along the main Tennessee River also will cause slight changes in release temperatures. At Chickamauga, for example, the increase in biweekly minimum flow could increase release temperature by 1 to 2°C (2 to 4°F) during stratified periods and decrease release temperature by 1°C (2°F) during more mixed conditions.

Dissolved oxygen: The three reservoir release alternatives include provisions for both increased minimum streamflow and aeration of selected dam releases. Increased minimum flows would have a significant effect on the dissolved oxygen (DO) content of releases from the lower seven mainstream reservoirs on the Tennessee River and could result in some improvement in the tailwater reaches of tributary reservoirs. However, DO improvement in tributary reservoir tailwaters would come primarily from aeration of releases and reduction in upstream pollution loads.

Providing biweekly average minimum flows from Chickamauga Dam and the six dams downstream during the warm, dry months from May through September is expected to help maintain DO levels of 4 mg/l in releases from those dams most of the time. Biweekly average minimum flows would limit the maximum residence time in each reservoir, which in turn would limit the consumption of DO by sediments and algae.

Daily average flows that are lower than current daily average flow targets could occur under a biweekly average flow requirement, particularly when power demand is lower on weekends and during brief periods of unseasonably cool temperatures. Lower daily flows may affect the assimilative capacity of the reservoir for existing point sources of pollution permitted by the states during dry years. The increased frequency of such flows, however, is expected to be small. An analysis of Tennessee River water quality below Chattanooga, an area with significant needs for assimilative capacity, showed that there would be adequate levels of DO with lower daily average flows for critical conditions.

Under current operating policies, the occurrence of zero daily average flow is rare (see table 19-A), and also is not expected to change significantly if biweekly rather than daily average minimum flow requirements are used. When modeling or monitoring indicates a problem from insufficient turbine operation over a period of several days, daily releases would be raised until conditions improve.

As explained in Chapter 3, the magnitude of releases through mainstream dams is only one factor contributing to DO problems during low flow periods in the summer and early fall on the Tennessee River. Other factors, such as the overall level of pollution control along the reservoir and withdrawal zone peculiarities of each hydropower unit, also affect the amount of DO in reservoir releases as much as, or more than, flow. Better understanding and manipulation of release dynamics at each dam and additional point and nonpoint source pollution controls could assist in preventing low DO in mainstream releases during low flow periods.

The reservoir release alternatives only specify biweekly average minimum flows on the seven lower mainstream reservoirs from May through September. From October to April, no biweekly average flows are specified. Rather, current daily average minimums have been lowered slightly to levels that are adequate to maintain downstream movement of discharges from point sources. This change is not expected to affect overall water quality significantly because air and water temperatures are cooler and DO concentrations are higher during this period.

Under reservoir release alternative A, aeration will raise DO concentrations to 4 mg/l in the tailwaters of Watts Bar, Fort Loudoun, and 14 tributary dams. Under alternative B, aeration and state action to control upstream pollution will raise DO concentrations to 5 mg/l in the tailwaters of Watts Bar, Fort Loudoun, and four tributary dams with warm water releases; and to 6 mg/l in the tailwaters of ten tributary dams with cold water releases. The same levels would be targeted under alternative C, but reached solely by aeration of releases through TVA dams. Under all release alternatives, aeration is provided only when turbines are in operation and the DO content of the tailwater would have been less than the target concentration.

Downstream of tributary dams, DO concentrations will continue to increase due to natural reaeration in free-flowing tailwaters. An increase of 0.5 to 4.0 mg/l (depending on the length of tailwater) can be expected due to natural reaeration while turbines are in operation; a higher increase will occur when only minimum flows are provided.

Modeling indicates that some marginal improvements in release DO can be expected as a result of improvements at upstream dams. For example, aerating releases from Watts Bar dam will increase the DO concentration at Chickamauga Dam by about a third of the increase provided at Watts Bar. Aerating the releases from Cherokee and Douglas dams will increase the DO from Fort Loudoun Dam by about one-sixth of the increase provided at Cherokee and Douglas.

Wetlands. No significant impacts on wetlands or wetlands development are expected under the reservoir release alternatives. In tributary tailwaters where the establishment of minimum flows substantially increases the wetted area, and where other conditions (e.g., soils and topography) are suitable, the extent of existing wetlands may increase and other small wetland areas may develop.

Wildlife. To the extent that improvements in flow and dissolved oxygen (DO) result in increased habitat and productivity of tailwater areas, wildlife will benefit. The principal beneficiaries are likely to be wading birds and furbearers.

Endangered and threatened terrestrial species: To the extent that improvements in flow and DO result in long-term increases in aquatic productivity (i.e., expansion of the available prey base) the two listed animal species (bald eagles and gray bats) would benefit. The green pitcher plant and Ruth's Golden Aster would be unaffected.

Aquatic Resources. Successful improvements in minimum flows and DO would provide substantial benefits to many biological resources. The amount of benefit would be directly related to how closely the improved flows and DO levels approach optimal conditions for the aquatic resources present.

The most obvious biological improvements would occur in tributary dam tailwaters. Of the 740 miles of unimpounded rivers and streams in the Tennessee Valley, about 210 miles presently are affected by lack of minimum flows. The increased flows provided under the reservoir release alternatives are expected to increase minimum wetted area in tailwater riffle reaches by 25 to 65 percent. This would permit recovery of over 180 miles--nearly 90 percent--of the impacted mileage (see table 25). The number of miles of large river habitat in the Valley with sufficient flows to support healthier and more diverse aquatic communities would be increased by about a third.

Restoration of DO levels to 5 mg/l (warm and cool water tailwaters) and 6 mg/l (cold water habitats) would create conditions supporting larger and more diverse benthic and fish communities. Permanent improvements in flow and DO would lead to increased diversity, greater benthic and fish production, and improved harvest. Some restored tailwater areas eventually could support reproducing populations of species now listed as endangered, and could lead to their removal from legal protection.

The effects of reservoir release alternatives on specific aquatic resources are discussed in more detail below.

Aquatic macrophytes: Changes in minimum flows or minimum dissolved oxygen (DO) levels under reservoir release alternatives A, B, and C would not influence aquatic macrophyte (vegetation) populations. However, abundant macrophytes, either growing in or transported into reservoirs, can increase the loss of oxygen from deep reservoir strata. Therefore, reservoir releases to assure minimum flows for habitat enhancement or maintaining DO content could be indirectly affected by abundant aquatic vegetation located further upstream.

Benthic invertebrates (benthos): Direct improvements in the production and standing crop of benthos would occur with the establishment of minimum flow; however, the improvement would be limited to increasing the numbers of stress-tolerant organisms that now survive in the tailwaters. Substantial concurrent improvements of minimum flows and DO would permit the reestablishment of diverse benthic communities.

Table 25
Effects of Release Alternatives
On Tailwater Regions

Reservoir	Avg. Length of Exposed Tailwater: No Action (miles)[1]	Avg. Length of Exposed Tailwater: Alt. A, B, or C (miles)[2]	Avg. Length of Tailwater Covered by Minimum Flow (miles)
Norris	13[3]	2	11
Cherokee	47	5	42
Ft. Patrick Henry	33[3]	3	30
Boone	0	0	0
So. Holston	14	1	13
Wilbur	8	4	4
Watauga	0	0	0
Douglas	25	5	20
Fontana	1	1	0
Ocoee No. 1	12	0	12
Ocoee No. 2	0[4]	0	0
Ocoee No. 3	0[4]	0	0
Blue Ridge	13	3	10
Apalachia	15[4]	2	13
Hiwassee	0	0	0
Nottely	14	1	13
Chatuge	18	1	17
Total	213	28	185
Percent of Total		(13%)	(87%)

Notes
1. Calculated as the distance from the dam to the point where local inflow equals the targeted minimum flow less leakage through the dam, or where backwater from a downstream dam occurs, whichever is less.
2. Distance required for turbine pulses to dampen to within 20 percent of the targeted minimum flow, or to reaeration weir (see table 20).
3. Exposed tailwater already covered by minimum flow.
4. Does not include cutoff tailwater between dam and powerhouse.

The species diversity of benthic communities is highly correlated with minimum DO levels. Recent analyses of data from tributary tailwaters indicate that improvements in benthic communities (e.g., increased species diversity, higher production) will occur with any increase in DO in the range of 0 to 7 mg/l. Achieving minimum levels of 5 mg/l in warm and 6 mg/l in cold tailwaters would allow development and protection of benthic communities characteristic of healthy warm and cold water stream systems. Short of meeting these standards, noticeable improvements could be expected if minimum DO levels were raised to at least 4 mg/l. No comparable data exist for benthic communities of mainstream tailwaters, but similar improvements could be anticipated in those situations where mainstream dams presently discharge water low in DO.

Mussels: Establishment of permanent minimum flows in tributary reservoir tailwaters could expand mussel habitat. If the temperature of these flows were suitable (i.e., warmer than the typical cold water releases noted, for example, in Norris Dam tailwater) and other habitat conditions remained suitable for a 20- to 50-year period, substantial mussel stocks could become established. Establishment of minimum flows in mainstream tailwaters would have no appreciable effect on either mussel habitat or population levels.

Improvements in minimum DO levels in tributary or mainstream reservoir tailwaters would enhance mussel populations. In addition to the direct survival and perhaps growth benefits, maintenance of higher DO levels would minimize the toxic effects of dissolved metals in the reservoir discharges. Such improvements would benefit mussel stocks directly and also would permit the establishment of more diverse fish populations, upon which mussels depend for host species to complete the reproductive cycle.

Establishment of minimum flows and improvement in DO in reservoir releases could lead to the recovery of some freshwater mussel stocks. The magnitude of the recovery would depend on several factors (e.g., long-term habitat stability, suitable temperatures, and reduction of toxic materials) in addition to flow and minimum DO levels. Published reports suggest that mussels typically require 5 mg/l DO for survival and 6 mg/l for growth. Recent TVA data suggest that mussels survive at DO levels below 5 mg/l, but do not address the requirement for growth.

Fish: In tributary tailwaters, improvements in flow regimes and DO levels would result in substantial fishery benefits. Minimum flows would provide increased habitat and more stable short-term thermal regimes; these conditions would benefit all aquatic organisms, both plant and animal. Improvement of DO levels to 5 or 6 mg/l appears to represent the best alternative for obtaining benefits in growth, health, and species composition of the fish community.

Establishment of minimum flows and improvements in DO levels in most tributary dam tailwaters would have no appreciable effect on fish populations in the body of the reservoirs. Minimum flows would have little effect on present tributary reservoir pool levels, and reservoir conditions generally would not be affected by aeration techniques, most of which work at the dam or in the tailwater rather than in the reservoir. Fish species of mainstream reservoirs that use tailwaters for spawning or nursery areas would benefit from increased DO and, where these species use tributary tailwaters, from more stable flow regimes.

Endangered and threatened aquatic species: Establishment of minimum flows and improvement in DO levels could lead to the enhancement of populations of endangered and threatened aquatic species. The degree of improvement in any tailwater would depend on the long-term stability of any new regime and could vary considerably for different listed species.

As discussed in relation to other aquatic organisms, establishment of minimum flows in tributary and mainstream tailwaters would help recover some of the river beds that once were suitable as fish and mussel habitat. Reestablishing the aquatic populations that once inhabited these habitats, however, also would depend on the restoration of higher DO levels and suitable temperatures.

Restoration of minimum flows and riverine water quality conditions downstream from the larger dams could reestablish large river habitats that were eliminated when the rivers were impounded.

Provided that stability is maintained, plant and animal organisms--including listed species--may repopulate these restored habitats, especially with assistance. If pursued on a broad scale, restoration activities could better ensure survival and recovery of several species now federally listed--the basic goal of the Endangered Species Act. Likely candidates include the pink mucket and orange-footed pearly mussel in the tailwaters of Cherokee and Douglas dams.

Scenic Resources. Under all three release alternatives, minimum flows from tributary dams would cover the stream bed in tailwater regions at all times at the point where turbine pulses which provide the flows have stabilized--a distance of 2 to 5 miles downstream of each dam. As shown in table 25, some 185 of the 213 stream miles exposed downstream of tributary dams would be covered by minimum flows under the alternatives evaluated in this study, significantly improving the scenic view of these tailwater regions. The 15 miles of exposed tailwater regions between the dam and powerhouse at Ocoee No. 2, Ocoee No. 3, and Apalachia dams would not be affected by these alternatives.

There will be no change in the scenic views of the tailwater regions of mainstream dams under these alternatives.

Navigation. Commercial navigation and mineral production along the Tennessee River system will not be affected by the reservoir release alternatives.

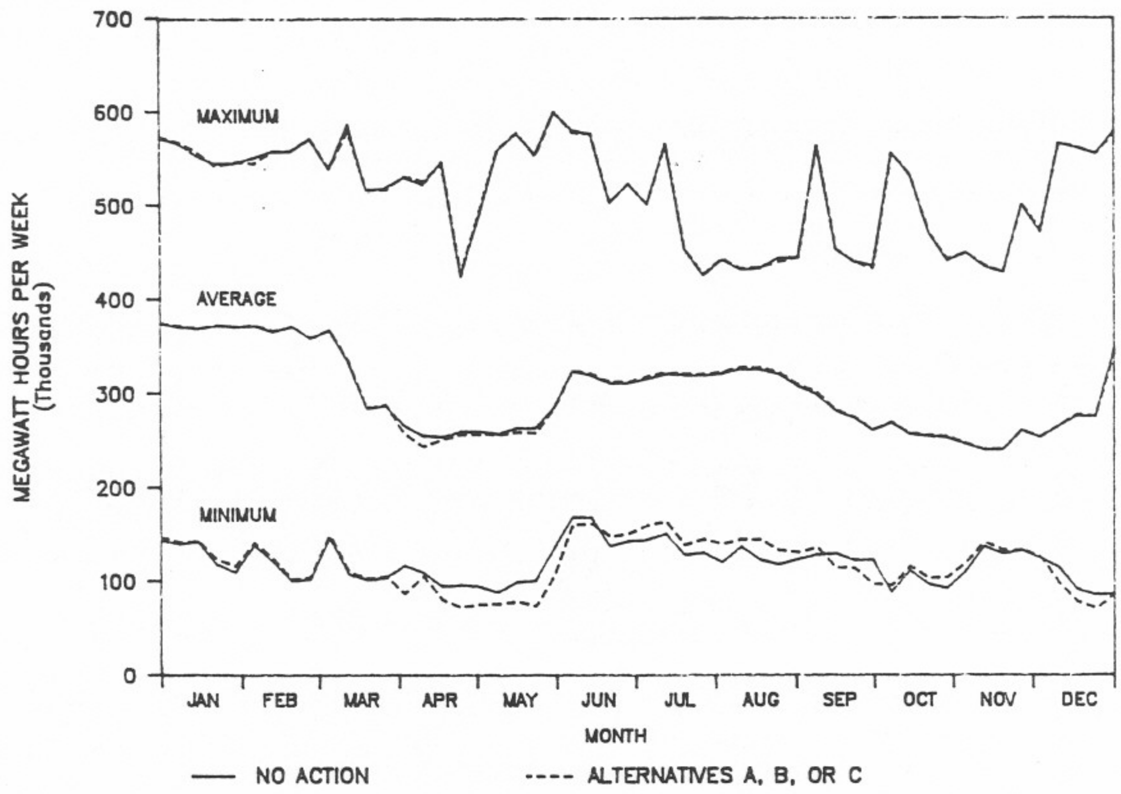
Flood Control. The benefits currently provided by the operation of TVA's reservoir system would remain the same under the reservoir release alternatives.

Hydroelectric Power. Providing minimum flows from mainstream and tributary dams would result in a net annual energy loss of about $50,000 per year in the value of hydropower generation. Additional generating capacity would not be required because effects on system reliability are minor.

Figure 16 shows the effect of providing minimum flows on weekly hydropower generation. There is no significant shift in seasonal hydropower generation compared to existing policies. There is a change in the weekly distribution of peak and off-peak generation between mainstream and tributary hydroplants, however. Providing minimum flows from tributary dams shifts about 2 million kilowatt hours of generation each week from peak to off-peak periods when it is less valuable to the power system. This amounts to about one-tenth of one percent of the average weekly hydropower generation shown in figure 16. At a difference of about $5 per megawatt hour in value between peak and off-peak energy, this is a loss in value of about $500,000 per year.

Providing minimum flows from mainstream dams as prescribed in alternatives A, B, and C provides a compensating benefit to reduce this cost. Biweekly average flow requirements during the summer and lower daily average flow requirements during the cooler months reduce the amount of off-peak generation

Figure 16
Effects of Reservoir Release Alternatives
On Weekly Hydropower Generation



needed to meet minimum flow targets under existing policies. This represents about a $450,000 benefit to the power system, reducing the overall cost of minimum flows at both mainstream and tributary dams to about $50,000 per year.

Thermal Generation. Providing minimum flows and DO will have little effect on the use of TVA's thermal generating sources (coal-fired, nuclear, and combustion turbine plants). The construction or operation of additional capacity for power system reliability will not be required because there will be no significant shift in seasonal hydropower generation compared to existing policies. The distribution of generation between mainstream and tributary hydroplants will change within each week, but this will have only a minor effect on the use of thermal generating sources. Operation of equipment for aerating the releases from TVA dams will require the consumption of electricity, but the amount used will not increase the use of thermal generating sources significantly.

Lake and Stream Recreation. The three reservoir release policy alternatives, by themselves, are not expected to change current patterns or levels of recreational use in tributary tailwaters significantly. Improving minimum flows and DO alone will not diversify the recreation opportunities available.

Water contact activities will not increase to any significant degree because the tailwaters will still be too cold; if one of the lake level alternatives is implemented at the same time, the water will be even colder during the summer months. The minimum flows are not great enough to enhance recreational floating opportunities to any great extent.

The quality of fishing activities in tributary tailwaters will be enhanced by providing minimum flows and DO because of improvements in the fishery and increased area for fishing. Significant increases in fishing activity, however, are dependent on other factors which are not affected by the alternatives: stocking of a large number of desirable sport fish, provision of improved access facilities, including walk-in access, boat access, parking, sanitary facilities, and transportation links from major population areas. As stated previously, public investment in stream access facilities has been lower than in lake access facilities, so these improvements are not likely to occur except in isolated cases.

In the tailwater below Norris Dam, where such improvements were made by the state of Tennessee, U.S. Fish and Wildlife Service, and TVA, recreational fishing use doubled. If stocking were increased and access improved below South Holston, Wilbur, and Tims Ford dams, and the Apalachia powerhouse, similar increases in recreational fishing use could occur. The tailwaters below Douglas, Chatuge, and Blue Ridge could support additional fishing pressure, but would need substantial improvements in access as well as stocking to reproduce the experience at Norris. Other tailwaters (Boone, Fort Patrick Henry, Cherokee, Nottely, and Ocoee No. 1) are not expected to experience significant increases in recreational fishing over current levels even if access and stocking are improved.

The use of turbine pulsing to provide minimum flows in tributary tailwaters will increase the exposure of tailwater users to the risk of being trapped or swept away by rapidly rising waters when the turbines are placed in operation. Turbine pulsing to provide minimum flows will cause about a 50-percent increase in the number of times during the week hydroturbines begin to discharge water into tailwater areas. However, the area of increased risk will be limited to the first two to five miles below the dam--the distance before the turbine pulses steady out sufficiently to provide a minimum instantaneous flow.

For years, TVA has posted signs, distributed pamphlets, and advised callers requesting turbine operation schedules to warn users of the hazards of rapidly rising water in tailwater areas due to hydroturbine operations. A review of existing warning signs and a special education effort to inform the public of the new operation and associated hazards to tailwater users is recommended in Chapter 6. Tailwater users also should be more aware of the rising and falling water levels because minimum flows are being provided.

Any risk presented by turbine pulsing to provide minimum flows is small compared to the risks accepted by other water recreation users, such as boaters or swimmers in lake areas. An average of 45 to 55 drownings per year occur on TVA lakes in the Tennessee Valley, which is a little less than the national average of 1.3 drownings per 100,000 population when compared to the regional population of 5.1 million. By comparison, only 4 drownings attributable to turbine operations have occurred in the past 25 years in the tailwater areas below TVA tributary dams.

Population and Income. The economic growth of counties adjacent to TVA reservoirs will not be significantly affected by improvements in minimum flow and DO because there will be no significant change in recreation visitation or shoreline development due to the reservoir release alternatives.

Land and Shoreline Development. Effects on land and shoreline resources due to the reservoir release policy alternatives are not expected to be significant. Improvements in minimum flow and DO principally affect the water resources of tributary tailwaters and releases from mainstream reservoirs. These changes are not expected to significantly increase land- or water-based activities associated with land and shoreline development trends or growth.

Cultural Resources. Provision of minimum flows using turbine pulsing will increase the number of turbine starts and shutdowns each year and could potentially affect slumping and wave erosion on banks in tailwater areas. More archaeological sites could be exposed and thus be subject to looting and vandalism.

There are stabilization and protection techniques which can deter slumping and bank erosion. These techniques will be implemented on significant archaeological sites, if they are adversely impacted by turbine pulsing. TVA's cultural resources program continues to experiment with techniques to protect archaeological sites from shoreline erosion and serves as the national clearinghouse for site stabilization techniques.

Lake Level Policy Alternatives

Water Quality. *Water temperature:* Delay of unrestricted drawdown for each of the lake level alternatives is not expected to have a significant impact on the onset of reservoir stratification. However, fall turnover could be delayed by several days to a few weeks. Deep water temperatures in the larger tributary impoundments could be on the order of $1^{o}C$ ($2^{o}F$) cooler at the beginning of the summer. During the warmest part of the summer, they would be 2 to $3^{o}C$ (4 to $5^{o}F$) cooler than current policies for the August 1 alternative, and as much as $9^{o}C$ ($16^{o}F$) cooler than under current policies for the October 31 alternative. Cumulative effects of cooler tributary releases are difficult to assess for the mainstream dams. However, crude estimates suggest that mainstream reservoir release temperatures would drop by 1 to $2^{o}C$ (2 to $4^{o}F$) during the warmest period of the year due to cooler tributary releases resulting from filling tributary lakes to higher levels in the spring and delaying unrestricted drawdown until August 1. The drop in release temperatures could be larger for alternatives 1A through 1D (under which unrestricted drawdown would start on August 1 for most reservoirs and on October 1 for others), and for the Labor Day and October 31 alternatives.

These effects are projected for median to dry years when turbine withdrawal of the cool deeper reservoir water is reduced to maintain stable pool levels. In wet years, the effects would be less because the cold water stored in tributary reservoirs would be rapidly depleted by higher releases. The net result will be a wider variation in release temperature from year to year. Reservoir surface water temperature is not expected to change.

Short-term fluctuations in tailwater temperature can be expected to increase if unrestricted drawdown is delayed. Because turbine operations pull water from the deep cooler layers, release temperatures will generally follow the temperature of the deeper reservoir water. Rapid temperature changes would occur when cold turbine releases mix with tailwater pools that have been warming between turbine operations. Since turbine downtime will be increased with delayed drawdowns and turbine release temperatures decreased, these tailwater temperature fluctuations would be expected to increase.

Minimum flow improvements under the reservoir release alternatives will have little effect on this overall temperature reduction, but they will reduce the size of expected tailwater temperature fluctuations by limiting the extent to which tailwater areas can warm when turbines are not in use.

If surface water pumps were installed to aerate the releases at other dams besides Cherokee and Douglas (see table 20), these temperature effects could be reduced by about 1 to 2°C (2 to 4°F), depending on the temperature profile of each reservoir. Additional pumps would be required to warm the releases more than 2 to 3°C (4 to 5°F). The effectiveness of using surface water pumps to mitigate temperature effects rather than for aeration would have to be evaluated on a case-by-case basis because surface water pumps have not been tested for this purpose. If too many pumps are installed to increase the temperature of releases, for example, bottom sediments could be stirred up, which can reduce the effectiveness of aeration and cause problems with iron, manganese, and hydrogen sulfide. Given this uncertainty and the cost effectiveness of other aeration technologies, surface water pumps are not recommended as a mitigation strategy for the effects of higher lake levels on release temperature.

Dissolved oxygen: For all lake level alternatives, releases through both tributary and mainstream dams would be reduced from the beginning of the spring filling period until the start of unrestricted drawdown to flood control levels. On mainstream reservoirs, reduced flow during all or part of the summer months would resemble flows during dry years with the accompanying reduction of DO. This reduction would be offset, to some extent, by maintaining biweekly minimum flows at selected mainstream dams under the reservoir release alternatives, which would reduce the frequency of DO levels under 4 mg/l occurring in the releases from mainstream dams.

In tributary reservoirs, the effect of maintaining higher pool levels on DO concentrations would vary by reservoir zone. Surface DO levels would increase in the upstream end of the reservoir due to extended backwater, which would stimulate algae growth and benefit fish populations. In the middle layer of the reservoir, however, DO problems would worsen roughly in proportion to the length of time higher tributary pool levels are maintained. Deeper pools and longer retention times, combined with the effect of decaying algae settling to the bottom and sediment oxygen demand, would increase the mass of water affected by low DO and extend the period of time before reaeration. This is particularly true in upstream reaches of tributary reservoirs where deeper pools occur less frequently under current lake level policies.

These changes in reservoir dynamics would not have a significant effect on DO in releases. Depletion of the cold water pool in the reservoir would occur at a less rapid rate because releases would be reduced, and oxygen depleted waters at the dam outlets would occur later in the year. Periods of low DO concentrations in turbine releases would begin two or more weeks later in the year; the lowest DO concentration would be the same or a little higher than occurs under existing policies. Under the Labor Day and October 31 alternatives, and on those reservoirs with lake levels held up to October 1 under alternatives 1A through 1D, delay of fall turnover would extend the period of low DO in releases further into the fall.

Delaying unrestricted drawdown until August 1 is unlikely to produce significant change from the conditions experienced under existing policies. Changes in both reservoirs and in releases would be more apparent if pools are held up through Labor Day or later.

Wetlands. Maintaining higher tributary pool levels could enhance wetlands and result in additional wetland development, although wetlands would still dry out after drawdown. The degree of wetland gains would be directly related to the duration of the higher pool levels. Holding higher pool levels through the late spring and early summer (alternative 1) primarily would benefit existing wetlands by increasing the hydroperiod--the time when a wetland is flooded. However, under this alternative, no appreciable development of additional wetland area would occur.

Holding higher pool levels through the summer (i.e., until Labor Day) would enhance existing wetlands through the extension of the hydroperiod and stabilization of water levels. Development of additional wetlands would probably occur. Portions of mudflat areas now exposed by drawdown would be covered for a longer period, allowing colonization by wetland vegetation species. Maintenance of high levels until October would further enhance both existing and developing wetlands.

Table 26 shows the potential for development of wetlands on each of the ten tributary reservoirs under alternatives 1A through 1D, 2 and 3. The potential for wetland development is based primarily on shoreline topography and the amount of shallow flooded areas near the shoreline. Table 26 shows that reservoirs with the steepest slopes, and the lowest wetland development potential, are those that have the largest portion of the shoreline in public ownership (table 4). The two principal public landholders on these reservoirs, the U.S. Forest Service and the National Park Service, keep these lands in forest, which helps to control erosion on the steep slopes of the shoreline.

Reservoirs with higher wetland development potential have a greater portion of their shorelands in private ownership. The characteristic which gives these reservoirs higher wetland development potential--moderately sloping shoreline topography--also makes their shorelands more attractive for commercial and residential development. The effects of the alternatives on shoreline development are discussed later in this chapter.

Wildlife. The effects of maintaining higher lake levels on wildlife would vary according to the regime adopted. Reducing the rate of drawdown in late spring and early summer is likely to have minimal impact. Slower drawdowns may benefit resident wood duck populations by providing more overbank and shoreline foraging habitat and shelter during the brood-rearing period. Slower drawdowns on some reservoirs would enhance the development of

Table 26
Potential of Tributary Reservoirs for Wetland Development
Under Lake Level Alternatives 1A through 1D, 2 and 3

High	Medium	Low
Douglas	Norris	Watauga
Cherokee	Chatuge	South Holston
	Nottely	Hiwassee
		Blue Ridge
		Fontana

vegetation in the wetter drawdown zones (e.g., spikerush) which is used extensively by resident Canada geese. However, a slower drawdown rate could curtail or force relocation of sharecrop farming activities in the Rankin Bottoms Wildlife Management Area on Douglas Lake. This would affect fall and winter food and habitat for doves and migratory waterfowl.

Extending higher pool levels through the summer (i.e., until Labor Day) would substantially increase the probability that annual aquatic macrophytes--a food source for several species of waterfowl--would become established. The longer duration of shallow overbank foraging habitat would benefit wading birds and wood ducks. Some species of migratory shorebirds which use the drawdown zone as foraging habitat would be negatively affected, as would some upland species of wildlife that feed on the vegetation which develops in the moist flats exposed by drawdown.

Further extension of the higher-pool period (i.e., until October) would have effects similar to those noted above. The probability of establishing annual macrophytes may increase, as would foraging opportunities for a greater number of migratory waterfowl species.

Endangered and threatened terrestrial species: Benefits to the listed animal species are likely to be directly proportional to the duration of summer pools levels. The benefits would result from the provision of increased foraging area and a higher prey base. No plant species is likely to be affected. Although the green pitcher plant is known to grow near at least one TVA reservoir (Chatuge), its continued existence appears to be independent of reservoir levels.

Adverse effects would be associated with substantial increases in recreational use and resulting human disturbance of feeding and nesting activities. Should such disturbances occur, management efforts (e.g., additional protection of habitats and establishment of refuge zones) should be effective in affording continued protection.

Aquatic Resources. Holding pool levels higher during the spring and early summer would provide more food and shelter for young fish and would increase the population of many sport and commercial species in tributary reservoirs. This would benefit fishing enthusiasts and other user groups.

Maintaining higher tributary pool levels for longer in the growing season could encourage the establishment of aquatic plant (macrophyte) growth in tributary reservoirs, benefiting benthic and fish stocks. Extensive macrophyte growth, however, could interfere with some water-based recreation. Water temperatures in tributary dam releases, and thus in tailwater areas, may be reduced as a result of holding higher pool levels, negatively affecting tailwater fisheries. This effect would be observed beginning in mid-summer; the extent of the temperature depression would be directly related to how long higher pools were maintained.

Aquatic macrophytes: Several macrophytes now established in mainstream reservoirs could become established in tributary reservoirs if present water-level regimes are substantially altered. Any decrease in the maximum drawdown of tributary reservoirs to levels where macrophytes could maintain continuing colonies would encourage the establishment of the perennials, Eurasian watermilfoil and hydrilla. These species commonly grow in depths of 3 to 5 meters (10 to 16 feet); hydrilla has the potential for growth in depths of 6 to 8 meters (20 to 26 feet). Once established, hydrilla could regenerate from tubers in the hydrosoil and survive even under present water level regimes.

Maintaining high water levels for longer periods during the growing season would increase the probability that annual, seed-producing species could become established. This would extend the mosquito breeding season, because the plants would remain in contact with the water longer. Once established, annuals would survive (i.e., the populations would be maintained through seed production) irrespective of the magnitude of winter drawdown.

Benthos: The effects on benthic organisms of delaying unrestricted drawdown on tributary reservoirs until later in the summer are likely to be neutral. Possible adverse effects associated with lower summer flows in tributary tailwaters could be avoided by establishment of suitable minimum flows and DO levels.

Mussels: Delaying unrestricted drawdown on tributary reservoirs until later in the summer should not adversely affect the freshwater mussel populations which remain in the tailwaters. To the extent that DO levels are higher, releasing the larger mass of retained cool water should have less effect on tailwater organisms (including mussels) than now occurs. If holding more water in tributary reservoirs results in lower summer flows to mainstream reservoirs, larger anoxic zones might occur, adversely affecting mainstream reservoir mussel populations. However, such possible impacts could be avoided if changes in tributary reservoir operating schedules were accompanied by the establishment of minimum flows under the release alternatives.

Fish: More aggressive spring filling of tributary reservoirs would benefit fish spawning by reducing the risk of decreases in pool levels during this critical period. Maintenance of higher pools through late spring and as late as October 1 with sloping recreation target levels (alternatives 1, 1A-D, or 2) would provide expanded, shallow-water habitat and thus would enhance the survival and growth of young fish and increase fish populations in tributary reservoirs. Other likely effects of maintaining higher tributary reservoir pool levels are an increase in access to the reservoirs and, ultimately, a corresponding increase in fish harvest.

Delaying unrestricted drawdown until October 31, however, could cause adverse effects. Fall drawdowns are beneficial to fish populations in tributary reservoirs because predator fish are concentrated with available prey, such as shad and sunfish. Increased spawning by these forage species often results the following spring, increasing the availability of small forage fish for the following year's small and medium size predator fish. Competition for food and space is also reduced, resulting in increased growth and a higher quality fishery.

Another effect of maintaining higher lake levels would be reduced tailwater temperatures in the late summer and early fall. This could enhance conditions for trout in several tributary reservoir tailwaters which reach temperatures above the optimal ranges for trout reproduction and growth. However, at other tailwaters that do not approach these limits, temperatures could be reduced below the optimal ranges for the trout species present and thus reduce growth rates.

If unrestricted drawdown is delayed until the end of October, temperature decreases of as much as 9^{o}C (16^{o}F) in the tailwaters will significantly impact tailwater fisheries. Where cold water fisheries currently exist, growth rates could be lowered significantly. An increased chance of thermal shocking also will exist due to increased temperature fluctuations. Current marginal conditions for warm water fisheries below Cherokee and Douglas dams could deteriorate significantly. Beginning unrestricted drawdown on August 1 will not have as negative an effect because tailwater temperatures are expected to be lowered only about 2 or 3^{o}C (4 to 5^{o}F) for that alternative. As noted above, this could benefit trout species in some tailwaters. Other adverse effects of higher tributary pools on tailwater fisheries, such as fluctuations in temperature, could be avoided or kept to a minimum if higher flows and DO levels were provided.

Endangered and threatened aquatic species: For the reasons presented earlier in the discussion on benthos, delaying unrestricted drawdown on tributary reservoirs until later in the summer should not have an adverse effect on endangered and threatened species in the tailwaters. Potential adverse effects on endangered mussel populations in the Tennessee River could be avoided if changes in tributary reservoir operating schedules were accompanied by the establishment of minimum flows under alternatives A, B or C.

Scenic Resources. Any increase in lake elevations that reduces exposure of the drawdown zone should increase the visual qualities associated with the shoreline. Table 27 shows that 36 percent of the average summer drawdown zone will be covered by keeping lake levels higher through August 1 (alternative 1); 67 percent will be covered by both the Labor Day and October 31 alternatives (alternatives 2 and 3). About 8 percent of the average fall drawdown zone will be covered under the August 1 alternative, 46 percent for the Labor Day alternative, and 80 percent for October 31 alternative.

Under alternatives 1A through 1D, groups of tributary reservoirs would be drawn down on different dates, so the percent of drawdown zone that would be covered has not been computed. Examining the amount of area covered by higher pools for each lake shows that alternatives 1A through 1D would cover, on the

Table 27

Effects of Lake Level Alternatives On Drawdown Zones

Reservoir	Average Summer Drawdown Zone[1] (acres)	Avg. Area of Summer Drawdown Zone Covered by Higher Pool Levels: Alt. 1 (ac.)	Alt. 1A-D (ac.)	Alt. 2 (ac.)	Alt. 3 (ac.)	Average Fall Drawdown Zone[1] (acres)	Avg. Area of Fall Drawdown Zone Covered by Higher Pool Levels: Alt. 1 (ac.)	Alt. 1A-D (ac.)	Alt. 2 (ac.)	Alt. 3 (ac.)
Norris	6120	2120	2870	4500	4520	12500	480	5650	4980	10140
Cherokee	7480	3060	3460	4890	4890	12300	1030	5280	6400	10520
Ft. Pat. Henry	–[2]	–	–	–	–	–	–	–	–	–
Boone	–[2]	–	–	–	–	–	–	–	–	–
So. Holston	570	190	250	170	170	1740	350	920	490	960
Wilbur	–[2]	–	–	–	–	–	–	–	–	–
Watauga	520	220	250	340	340	1050	90	450	370	720
Douglas	5160	1840	2250	3960	3960	12500	1040	6190	6370	10660
Fontana	2020	780	860	1010	1020	3520	360	1450	1600	2470
Ocoee No. 1	–[2]	–	–	–	–	–	–	–	–	–
Ocoee No. 2	–[2]	–	–	–	–	–	–	–	–	–
Ocoee No. 3	–[2]	–	–	–	–	–	–	–	–	–
Blue Ridge	210	80	90	190	190	760	80	310	420	680
Apalachia	–[2]	–	–	–	–	–	–	–	–	–
Hiwassee	820	200	220	360	360	1810	150	660	800	1220
Nottely	1110	320	410	720	720	1790	140	600	810	1290
Chatuge	1030	320	450	580	580	2000	130	800	710	1450
Total	25040	9130		16720	16750	49970	3850		22950	40110
Percent of Total	100	36		67	67	100	8		46	80

Notes

1. The area of the unvegetated zone around each reservoir that is visible in the summer or fall is calculated as the difference between lake surface area at normal maximum pool and average summer or fall lake surface area under existing policies.
2. The area of the drawdown zone for Boone, Ft. Patrick Henry, Wilbur, the Ocoee reservoirs, and Apalachia would not change.

average, a little more of the summer drawdown zone than alternative 1 (August 1 drawdown date) and a little less of the fall drawdown zone than alternative 2 (Labor Day drawdown date).

Under all alternatives, at least part of the summer or fall drawdown zone is usually exposed because tributary reservoirs can be filled to normal maximum pools (the top of the unvegetated zone) in only 20 to 30 percent of the years due to limited rainfall (compared to 10 to 20 percent of the years under current operations). The annual drawdown remains unchanged for all tributary lakes, so visual quality during the winter months is unaffected by the lake level alternatives.

If visual quality were ranked on a scale from 1 to 10, based on the judgment of TVA staff, the visual quality in the summer would increase from a 5 to a 7 for the August 1 alternative and for alternatives 1A through 1D. Visual quality would rank an 8 or 9 for the Labor Day and October 31 alternatives. The visual quality on an annual basis would increase from a 5 to a 6 or 7 for each of the alternatives. However, visual quality or aesthetics is highly subjective and each individual's perception of these changes and value placed on them will vary.

Navigation. Flow requirements for commercial navigation at Pickwick and Kentucky dams were included in the analysis of the lake level alternatives; hence, water depths for navigation would not be impacted. Similarly, the lake level alternatives are not expected to impact mineral production along the Tennessee River system.

Navigation on the lower Ohio and Mississippi rivers could be affected, however. Compared to the no action alternative, holding reservoir levels up in TVA tributary lakes reduces the weekly average flow at the mouth of the Tennessee and Cumberland rivers (see figures 11-A and 11-B). For the October 31 alternative, water depths for commercial navigation on the lower Ohio and Mississippi rivers would be decreased during September and October. This also would be true during September for alternative 1A, under which unrestricted drawdown on Knoxville area reservoirs (Norris, Cherokee, and Douglas) is delayed until October 1. In a dry year, the effect would be significant and could impair the ability to navigate those rivers. During the 1988 drought, for example, the Tennessee River provided a significant portion of the lower Ohio River flow during the late summer and fall period, enabling commercial navigation to continue using the river. If the October 31 or the Knoxville area alternative had been in effect in 1988, commercial navigation would have been impacted more severely.

In contrast, commercial navigation on the lower Ohio and Mississippi rivers during this period could be aided, particularly during a dry year, under the Labor Day and August 1 alternatives, and the alternatives under which unrestricted drawdown on the Tri-Cities area, Fontana, or Hiwassee basin reservoirs is delayed until October 1 (alternatives 1B, 1C, and 1D). Under these alternatives, drawdown of the tributary lakes would begin during September and October, increasing the weekly average flow at the mouth of the Tennessee and Cumberland rivers during their low flow period.

The magnitude of the decrease or increase in water depths on the lower Ohio and Mississippi rivers would depend on the relative magnitude of the flows in the Tennessee and Cumberland rivers, but typically would be no more than 1 to 3 feet. However, changes of this magnitude can be very important to navigation (and flood control) operations conducted by the U.S. Army Corps of Engineers on those rivers.

Flood Control. The lake level alternatives would not have a significant effect on the capability of the TVA reservoir system to control floods in the Tennessee Valley. As discussed in Chapter 1, summer floods usually affect only a portion of the region at one time. Studies of the probable maximum summer flood show that dam and nuclear plant safety are not threatened by increasing the average summer reservoir levels as long as they are no higher than the normal maximum pool. Similarly, expected flood damages at communities along the Tennessee River and its tributaries, including Chattanooga, are not significantly increased.

Outside the Valley, however, there could be some flood control effects similar to the navigation effects described previously. For the October 31 alternative, flow from the Tennessee and Cumberland rivers would increase during November and December due to more rapid drawdown of tributary lakes to flood control levels. This could interfere with the Corps' flood control operations, which depend on flood storage space in Kentucky and Barkley lakes to store Tennessee and Cumberland river flows and thereby reduce river stages at Cairo, Illinois, and other locations. Stored flood water could rise to and threaten to exceed TVA's easement levels in Kentucky Lake, and could increase flooding on the lower Ohio and Mississippi rivers.

The concerns about flood control on the lower Ohio and Mississippi rivers for the Labor Day alternative and for alternative 1A, under which unrestricted drawdown on Knoxville area reservoirs (Norris, Cherokee and Douglas) is delayed until October 1, are not as great as those for the October 31 alternative. Concerns about flood control for the August 1 alternative and the alternatives under which unrestricted drawdown on the Tri-Cities area, Fontana, or Hiwassee basin reservoirs is delayed until October 1 (alternatives 1B, 1C, and 1D) are considerably less.

Hydroelectric Power. Providing higher tributary lake levels during the summer and fall months would reduce the value of hydropower generation and could require additional capital investments in new generating facilities by the mid-1990s to assure the reliability of the overall power system during the summer peak season. Table 28 summarizes these costs for all alternatives. Significant power costs are incurred under alternatives 2 and 3, involving the eventual replacement of 750 megawatts of capacity.

The shifting of hydropower generation as a result of keeping tributary lake levels higher during the summer and fall months is shown in figure 17. Hydropower generation is reduced beginning in mid-March as reservoirs are filled more aggressively than under existing policies. This reduced generation continues until the end of the recreation target level period, which varies in duration with each alternative. When unrestricted drawdown is permitted (August 1 for alternative 1, August 1 for some reservoirs and October 1 for others under alternatives 1A through 1D, Labor Day for alternative 2, and October 31 for alternative 3), hydropower generation increases above what it would have been under existing policies, and continues higher than normal through the end of the calendar year until the beginning of the flood control season on January 1. As discussed in Chapter 4, there would be no change in hydropower generation at Cumberland River dams from which TVA receives power under arrangements with the Corps of Engineers and the Southeastern Power Administration.

For alternatives 2 and 3, this change in the pattern of hydropower generation shifts over 1.3 billion kilowatthours from the spring and summer into the post-Labor Day period. Not only is the value of this energy reduced by producing it during the fall rather than the summer, some 750 megawatts of additional capacity must be obtained to produce the displaced summer energy.

Table 28
Power Costs for Lake Level Alternatives

Alternative	Annual Energy Cost Average ($m)	Annual Energy Cost Range ($m)	Required Capacity Addition (mw)	Initial Capital Cost ($m)	Annual Capital Cost ($m)	Total Annual Cost[1] ($m)
1 (August 1)	2	-9 to 20	0	0	0	2
1A (Knoxville)[2]	6	-7 to 30	100	74	9	15
1B (Tri-Cities)[2]	9[3]	-9 to 20	10	7	1	10
1C (Fontana)[2]	3	-9 to 20	30	22	3	6
1D (Hiwassee Basin)[2]	3	-9 to 20	0	0	0	3
2 (Labor Day)	16	-4 to 60	750	560	68	84
3 (October 31)	25	-4 to 56	750	560	68	93

Notes:
1. The total annual cost is the expected average cost over a period of several years; actual annual costs could be as much as $20 million higher or lower from year to year, depending on rainfall and runoff. By comparison, the average annual value of hydropower generation is $300 to $350 million, ranging in any year from $170 to $450 million depending on rainfall and runoff.
2. Rapid drawdown for reservoirs in this group begins on October 1, while unrestricted drawdown on all other reservoirs begins on August 1.
3. The annual energy cost of alternative 1B includes changes in operation at John Sevier Fossil Plant, which relies on Tri-Cities area reservoirs for cooling water (see Chapter 2).

If this capacity is not obtained, the capability of the power system to meet the peak load during the summer is reduced, leading to a greater probability of power being curtailed or voltage reduced in certain areas when demand exceeds supply.

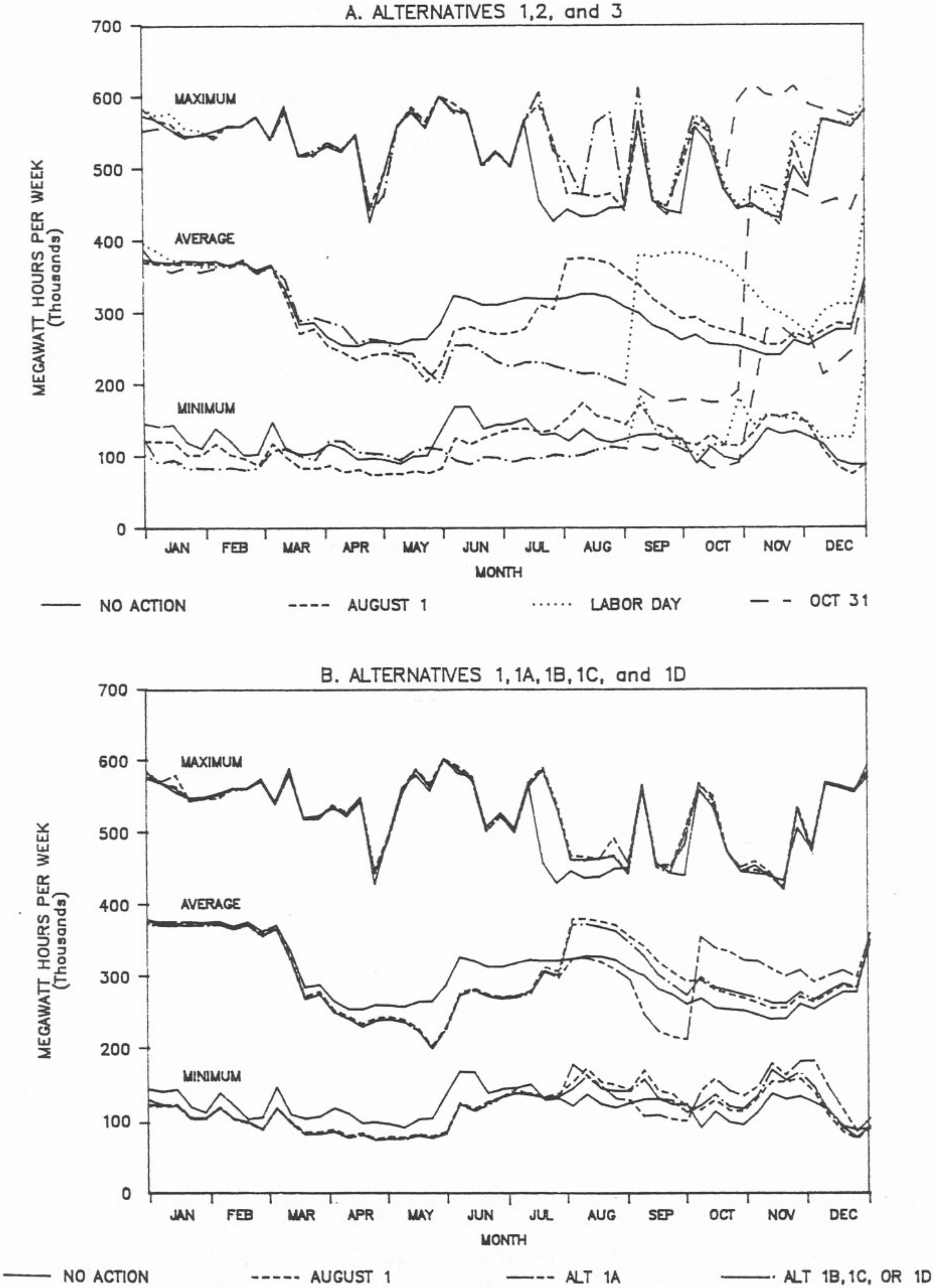
For alternative 1, a significant amount of the shifted hydropower generation (about 240 million kilowatthours) can still be used during the last half of the summer when the highest weekly power demands are most likely to occur. About 310 million kilowatthours would be shifted into the period between Labor Day and January 1. The average annual loss in the value of hydropower energy is about $2 million. However, this value would vary widely from year to year depending on rainfall--from a $20 million loss to a $9 million benefit. Similar variation would be expected for alternatives 2 and 3.

The potential capacity cost for alternative 1 that was reported in the Draft Environmental Impact Statement has been eliminated as a result of the development of detailed implementation procedures by TVA staff using the approach presented in Chapter 4. This approach assures that hydropower is still available to TVA as a resource to meet critical power system needs without significantly affecting lake levels.

For alternatives 1A through 1D, the amount of hydropower generation shifted from the spring and summer to the post-Labor Day period is much less than for alternatives 2 and 3, but more than alternative 1. Hence, losses in the value

Figure 17

EFFECTS OF LAKE LEVEL ALTERNATIVES ON WEEKLY HYDROPOWER GENERATION



of hydropower energy and capacity costs for these alternatives show similar variation. The cost of these alternatives is reduced because unrestricted drawdown in delayed to October 1 on only one to four reservoirs and because sloping recreation target levels are specified. There is no capacity cost for the Hiwassee basin alternative (October 1 drawdown on Blue Ridge, Hiwassee, Nottely, and Chatuge) because the storage capacity and generating capability of these reservoirs is relatively small.

Thermal Generation. Some of the lake level alternatives can have a significant effect on the seasonal use of thermal generating sources and require capacity additions to maintain power system reliability. To assess the full range of possible environmental effects, this study assumed that fossil-fueled sources will be used in the short term and constructed in the long term to supply these needs. As a practical matter, only fossil-fueled sources are available in the short term. In the long term, this assumption is conservative (i.e., the maximum possible environmental effects would be predicted). Other options could be chosen to meet power system capacity needs with fewer environmental effects, such as energy conservation, or may be required by future environmental laws and regulations, such as the recently enacted changes to the Clean Air Act.

Lake level alternatives cause shifts in hydropower generation from the period when recreation target levels are in effect to later in the year. When hydropower use is lower (beginning in the spring and extending as late as October 31 under alternative 3), there will be increased thermal generation; when hydropower generation is increased later in the year, thermal unit generation will decrease. Under alternative 3, there also could be an overall increase in thermal generating plant usage due to increased spills of water during major summer storms when lake levels are high, and during drawdown in November and December when rainfall is greater than usual.

This will result in minor changes in discharges of cooling water and solid and liquid wastes from TVA thermal generating plants and changes in emissions to the air. The estimated annual average increase in emissions of air pollutants and carbon dioxide from extending summer pool levels through the end of October (alternative 3) would be about one percent of current coal-fired plant emissions; the highest expected annual average increase would be about two percent. The overall increase in the burden of pollutants in the environment would be similarly small. Slightly lower increases would be expected for summer pools through Labor Day (alternative 2), and much lower for summer pools through August 1 (alternative 1) and for higher pools on selected tributary reservoirs until October 1 (alternatives 1A through 1D). These increases in emissions would be spread among a number of plants across the TVA region. Emission rates would not be greater than the allowable rates for these plants. The potential impacts on stratospheric ozone and greenhouse gases, and their resulting effects, would not be detectable.

On a seasonal basis, some changes in ambient concentrations of air pollutants would occur. Decreases in emissions would occur when lake levels are lowered, providing hydropower to replace other generation. Increases would occur during the period lake levels are extended. For alternative 3, the average increase in emissions would be about six percent over current summer levels, ranging as high as eight to ten percent in a worst-case year.

Because dispersion conditions are worse in the summer and pollutant transport is slower, there may be some small increases in acid deposition and ambient air pollutant concentrations during the summer months under alternative 2 and, especially, under alternative 3. The effects of alternatives 1 and 1A through 1D would be much less than the other alternatives because of greater hydropower generation during the summer. Any such increases, however, still would be within allowable permit limitations.

If new fossil-fueled capacity were added to TVA's power system, it would have to comply with regulations for the prevention of significant deterioration, including the use of best available control technology at the time of construction and new source performance standards, and any additional or more stringent requirements that could arise from new laws or regulations. The rate of emissions from a new fossil-fueled plant would be less than from existing plants, but no significant change in the effects discussed previously would be anticipated.

Lake level alternatives would increase the frequency of lower flows (above the minimum flow requirements but below the monthly average flow) on mainstream reservoirs during the late winter and early spring. This could cause minor additional use of cooling towers at Sequoyah Nuclear Plant and/or small increases (within discharge permit limits) in the magnitude of temperature rises. In the summer, cooler water temperatures in releases from tributary dams would help the thermal plants meet thermal compliance and safety limits and may increase plant efficiency due to lower intake water temperature.

Changes in the amount and seasonal production of liquid and solid wastes and cooling water discharged from fossil-fueled plants is not expected to be measurable. The additional amount of these pollutants and discharges will not exceed the amounts allowed in environmental permits received from regulatory agencies for each TVA plant.

<u>Lake and Stream Recreation.</u> Each of the lake level alternatives will increase recreational use of TVA tributary reservoirs as a result of improved land-water-facility relationships during the summer vacation season. Recreation use was estimated using a facility-based model that included parameters for occupancy rates, group sizes, weekend use rates, and the carrying capacity of various types of water-based facilities. To more accurately reflect recreation use changes due to reservoir operation changes, adjacent facilities such as golf courses and swimming pools were not included. In addition, the estimates do not include such recreation uses as driving for pleasure or sightseeing.

Recreation use was estimated assuming recreational use of the reservoirs is principally related to water access facilities along the reservoir. Water-related recreational use from both public and privately owned undeveloped land along the reservoir shoreline was estimated based on usage of these formal access facilities. Recreational use of the lake by owners of developed shoreline lands is discussed in a separate section (see "Land and Shoreline Development," below).

As shown in table 29, holding tributary lake levels higher through Labor Day is expected to increase recreation visitor-days by 38 percent compared to the no action alternative. (These increases were estimated based on an inventory of existing facilities and current usage rates. Staff judgment and interviews with facility operators were used to estimate increased use under each lake level alternative based on remaining capacity.) A relatively small additional increase in visitor-days is expected if higher lake levels are maintained through the fall color season (October 31) because schools are back in session.

A 21-percent increase in visitor-days (a little more than half the increase expected under the Labor Day alternative) is expected if higher lake levels are maintained until August 1. Increased visitation for alternatives 1A through 1D, under which unrestricted drawdown on some reservoirs is delayed until October 1 while unrestricted drawdown on others begins on August 1, is a few percentage points higher than the expected increase for alternative 1. The exception is the Knoxville area reservoirs (alternative 1A), where visitation is expected to increase by about 32 percent.

Increased recreation use will not be uniform among the ten tributary reservoirs affected by the alternatives even if all reservoirs begin unrestricted drawdown on the same date, as shown in table 30. Although not statistically related, the percentage increases in visitation are roughly correlated with percentage increases in average summer lake area (shown in table 23 in Chapter 4).

Generally, the number of commercial and public recreation access facilities (launching ramps, boat docks, slips, etc.) is adequate on the affected tributary reservoirs. Under alternative 1, existing facilities would receive higher levels of use as a result of increased visitation, but little expansion would be likely because of continued reduced patronage during August. If higher lake levels were maintained until Labor Day or beyond, expansion of recreation access facilities would be likely, but most of it would be expansions of existing campsites, cabins, boat slips, launching ramps, parking, etc. For example, the number of boat slips and campsites would be expected to increase about 15 to 20 percent for the Labor Day alternative. Under all alternatives, drawdown to winter levels would continue to occur, discouraging major expansion efforts and development of new areas.

Table 29

Increased Annual Visitor-Days for Tributary Reservoirs

Alternative	Total Visitor-Days (millions)	Increased Visitor-Days (millions)	Change (%)
No Action	4.4	-	-
August 1	5.3	0.9	21
1A (Knoxville area)	5.8	1.4	32
1B (Tri-Cities area)	5.5	1.0	23
1C (Fontana)	5.4	1.0	22
1D (Hiwassee basin)	5.5	1.1	24
Labor Day	6.1	1.7	38
October 31	6.3	1.9	44

Table 30
Increased Annual Visitor-Days by Reservoir

Reservoir	Current Annual Visitor-Days (millions)	Increase Annual Visitor Days Per Alternative						
		1 (%)	1A (%)	1B (%)	1C (%)	1D (%)	2 (%)	3 (%)
Norris	1.40	23	41	23	23	23	41	49
Cherokee	0.64	29	49	29	29	29	49	56
Douglas	0.50	24	42	24	24	24	42	48
Chatuge	0.51	12	12	12	12	25	25	28
South Holston	0.33	17	17	29	17	17	29	35
Fontana	0.20	32	32	32	53	32	53	59
Watauga	0.09	23	23	33	23	23	33	40
Nottely	0.14	8	8	8	8	17	17	20
Blue Ridge	0.11	22	22	22	22	32	32	35
Hiwassee	0.50	14	14	14	14	36	36	37
Average		21	32	23	22	24	38	44

Additional recreational use of the ten tributary reservoirs will result in a minor increase in soil erosion due to wave wash from boats and in nuisance problems related to boating, such as speeding, drunk driving, noise, hunting from boats, and dumping of trash and houseboat wastes. Conflicts among lake users also will intensify with increases in recreational use of these lakes.

Population and Income. Current economic growth in the areas around the ten tributary reservoirs due to recreation, tourism, and second home development will be less constrained by summer drawdown under each of the lake level alternatives. However, any increase in the current rate of growth that might occur if one of the alternatives is implemented would be difficult to attribute to improved lake levels.

This is because summer and fall lake levels are only one of several factors affecting economic growth. For example, counties in northern Georgia and southwestern North Carolina are experiencing high population and income growth (as shown in table 11-B, Chapter 3), although reservoirs in these areas are subject to large summer and annual drawdown. This growth is probably the result of a combination of factors--the beauty of the area's mountains; the proximity of reservoirs in northern Georgia and southwestern North Carolina to major population centers such as Atlanta; the improved transportation access to these reservoirs; and the development of a new state park in the region.

The presence of TVA reservoirs in northern Georgia and southwestern North Carolina is probably a significant factor in attracting second home development to the region, despite significant summer and annual drawdown under current policies. If summer drawdown could be delayed, the attractiveness of lakes in this region would increase, and would probably help stimulate further economic growth. However, if this economic growth were not already occurring, it is doubtful that improved summer lake levels would encourage the growth to begin.

Counties near Kentucky and Pickwick reservoirs on the main Tennessee River, which have very small annual drawdown and virtually no summer drawdown, are experiencing low and negative growth in population and income (see table 11-A).

Determining the effect of improved summer and fall lake levels on economic growth is difficult and has not been attempted in quantitative terms. Qualitatively, it is reasonable to conclude that such improvements will increase growth to some degree, but it is not likely to be predictable or measurable. Similarly, it can be concluded that the longer higher lake levels are maintained, the greater the attractiveness of the lakes and the greater resulting economic benefits to the surrounding communities, many of which are plagued by low per capita income and high unemployment.

Local governments near the ten tributary reservoirs affected by the lake level alternatives have accommodated growth in their communities without significant adverse effects on their finances or service levels. In the judgment of TVA staff, this situation should not change under any of the lake level alternatives. If the rate of development were to increase considerably over what has been experienced in the past, some local governments may have problems accommodating the growth. This is not likely, however, in the judgment of staff.

Land and Shoreline Development. Exposure of at least part of the drawdown zone in summer and annual drawdown in winter will continue to affect the development potential of tributary reservoirs. By delaying summer drawdown, however, the lake level alternatives would make the ten tributary reservoirs affected more attractive for shoreline development. How much more attractive would depend on how long higher lake levels are maintained, as well as the amount of the drawdown zone that would be covered.

Whether this attractiveness results in increased shoreline development depends on other economic and demographic factors, such as population, land ownership, and accessibility from population centers. Table 12 shows the expected rate of development in the 1990s of the shoreline around TVA reservoirs. Nine of the ten reservoirs affected by the lake level alternatives (Norris, Cherokee, Douglas, Chatuge, South Holston, Watauga, Nottely, Blue Ridge, and Hiwassee) are expected to experience high and medium growth around the shoreline whether or not lake levels are kept higher longer. Little additional development is expected around Fontana, which is in the low growth category, because much of the shoreline is publicly owned. However, the agencies that control this land may face increased pressure to make it available for public or private development if lake levels are held higher longer.

Chatuge and Nottely reservoirs, the only two reservoirs expected to experience high growth, have 122 miles of privately owned shoreline property. Both reservoirs are firmly established as second home markets, principally for people from Atlanta and Florida. Almost half of the available privately owned shoreline is developed on Chatuge; somewhat less on Nottely. Extended summer pool levels will not affect the type of residential development underway, but will increase the use of these second homes. Additional shoreline development, coupled with overall economic growth due to other factors, could create demand for property adjacent to developed shorelands. The present value of higher pool levels through October 31 over a 15-year period is about $11 million, using data collected by the state of Georgia for this study. Lesser values would be expected for the Labor Day and August 1 alternatives, or if unrestricted drawdown were delayed until October 1 on these reservoirs under alternative 1D.

Norris, Cherokee, and Douglas reservoirs, the largest of the reservoirs expected to experience medium growth, have over 900 miles of privately owned shoreline property which is being developed primarily for permanent residences and weekend retreats. Approximately 10 percent of the privately owned shoreline around these lakes has been developed for single family residences. Extending higher lake levels to Labor Day or beyond would create more interest in permanent residences and help these areas compete with Fort Loudoun, Melton Hill, and Tellico, which are experiencing high growth due to residential development probably attracted, in part, by their smaller annual and summer drawdowns. The net present value of higher pools through October 31 on Norris, Cherokee, and Douglas would be about $9 million using similar data to those used for Chatuge and Nottely. Lesser amounts would be expected for the Labor Day and August 1 alternatives, or if unrestricted drawdown were delayed until October 1 on these reservoirs under alternative 1A.

The other four reservoirs expected to experience medium growth--South Holston, Watauga, Hiwassee, and Blue Ridge--have only 117 miles of privately owned shoreline. Growth around these reservoirs is limited by large public landholdings. The greatest amount of available land exists around Watauga and South Holston, which are attractive alternatives to Boone and Fort Patrick Henry reservoirs because of good water quality and available land. Development around Hiwassee and Blue Ridge will be influenced by the same factors affecting Nottely and Chatuge.

Like other areas experiencing similar growth pressures, localities around reservoirs where shoreline development is expected to grow at a high or medium rate in the 1990s are likely to experience some negative effects if controls on the type, extent, and quality of shoreline development are not implemented either by local governments or the landowners themselves. Socioeconomic impacts from substandard development include reduced public revenue, increased cost of public services, and an inhibiting effect on the quality of development on nearby property. Environmental impacts, as stated previously, include loss of aquatic and riparian habitat for fish and wildlife, nonpoint source pollution from soil erosion and user activities on developed shorelands, and changes in the visual quality of the natural shoreline.

Whether the cumulative impact of increased shoreline development will reach significant proportions earlier as a result of the lake level alternatives than it would with existing rates of development is difficult to determine. Staff judgment is that the added effects due to the alternatives will not significantly accelerate problems related to cumulative impact.

Minimizing environmental effects due to shoreline development will require the cooperation of all levels of government. Potential cumulative impacts can be controlled through local and state government action (e.g., subdivision development standards, nonpoint source pollution standards, and required use of Best Management Practices), combined with enforcement of public shoreline use and development policies by TVA and other federal agencies.

Cultural Resources. Leaving tributary lake levels higher during the summer and fall periods would lengthen the amount of time some archaeological sites are covered with water, decreasing their availability to looters. Increased shoreline development resulting from the lake level alternatives, however, could affect historic structures and small towns with historical districts situated in the areas of development. If development occurs on TVA land as a result of the lake level alternatives, or developers request special access through TVA lands, TVA must evaluate the effects of development on affected historic properties under the provisions of the National Historic Preservation Act. Where development occurs on private lands, without federal funds, there is no federal procedure for review and protection of historic properties. States and counties may have historic zoning and other protection statutes.

SECTION THREE: RECOMMENDED PLAN OF ACTION

Chapter 6

Preferred Alternatives and Supporting Recommendations

This study proposes that TVA reservoir operations be modified to delay summer drawdown in tributary lakes, maintain increased minimum flows below tributary dams and in main Tennessee River reservoirs, and, where necessary, increase dissolved oxygen in releases from TVA dams to improve water quality and protect aquatic life.

The preferred release alternative is to provide minimum flows affecting all dams, plus increase dissolved oxygen in tailwaters to a level of 5 or 6 milligrams per liter through aeration of releases from 14 tributary dams and two mainstream dams and state action to control upstream pollution (alternative B).

Implementation of this alternative should improve water quality and aquatic life throughout the Tennessee River system. No adverse impacts are expected. However, to respond to public concerns expressed during review of the Draft Environmental Impact Statement (EIS), two commitments are recommended in conjunction with release improvements. First, TVA should take steps to inform the public of the hazards associated with providing minimum flows by turbine pulsing. Second, TVA should monitor the effects of the proposed biweekly average summer flow requirements at mainstream dams on water quality and aquatic life.

In support of the proposed release improvements, the study further recommends that TVA:

- work with the states to implement release improvements within a five-year period, tailoring actions to the specific needs at each dam,

- focus its aeration research on autoventing turbine technology, and

- work with interested local areas to find ways to finance releases for recreational floating.

The preferred lake level alternative is to fill 10 tributary lakes more aggressively and maintain recreational pools levels until August 1 (alternative 1).

Implementation of this alternative would enhance recreation on tributary lakes and provide economic development benefits. No significant adverse impacts have been identified. However, to respond to public comments received on the Draft EIS, TVA should commit to monitoring shoreline development trends if lake level improvements are made.

Also in conjunction with delaying unrestricted drawdown of tributary lakes, the study recommends that TVA:

- promote a balanced use of reservoir shorelines through its land management activities.

Other recommendations developed in response to concerns raised during the study include:

- improving communication with lake users,

- reasserting TVA leadership in navigation development, and

- monitoring and planning for the effects of climate change on reservoir operations.

This chapter explains why reservoir release alternative B and lake level alternative 1 are preferred and presents the rationale for the proposed environmental commitments and other recommendations.

Rationale for Preferred Reservoir Release Alternative

Four reservoir release alternatives were evaluated, as described in Chapter 4. Under the no action alternative, TVA would continue to follow existing release policies. Under alternatives A, B, and C, TVA would provide increased flows and aerate the releases from Watts Bar, Fort Loudoun, and 14 tributary dams. The same flows would be provided under these alternatives, but the dissolved oxygen (DO) improvement targets specified under alternatives B and C would be higher than under alternative A. In addition, alternative B counts on concurrent action by states to control upstream pollution sources affecting tailwater areas, while alternatives A and C do not.

Alternative B is recommended primarily because it would provide significantly more benefits to water quality and aquatic life in proportion to the added costs. The rationale for selecting alternative B over the no action alternative and alternatives A and C is discussed in detail below.

The no action alternative is not recommended primarily because of the effect on water quality. The most pervasive water quality problem in the TVA reservoir system is the occurrence of low DO. While point and nonpoint sources of pollution contribute to this problem, it is caused principally by natural processes resulting from reservoir design and impoundment and how water is released from TVA dams.

Dissolved oxygen in the bottom portion of TVA reservoirs--especially deeper tributary reservoirs--is depleted in the summer as a result of unavoidable physical and biological processes. Hydroturbines at TVA dams, operating to meet summer power demands, withdraw water from this lower layer, thus releasing low DO water during some periods. This stresses aquatic life in the tailwater area and reduces the quality of water available for other uses (e.g., drinking water and assimilation of wastes). Improvements in the DO level in tailwater areas are expected under existing policies, but the rate of improvement likely will not resolve this problem before the end of this century.

The no action alternative also is not recommended because of the effects of current operations on flow regimes in tailwater areas. Over 200 miles of tailwater regions (nearly 30 percent of the 740 miles of unimpounded large river habitat in the Tennessee Valley) currently consist of a series of shallow pools and exposed riffle areas when hydroturbines are not operating. This has far-reaching effects on the health, number, and diversity of aquatic life, including some species now listed as endangered. It also impacts the quality of fishing activities in reservoir tailwaters and detracts from the scenic beauty of these areas.

Under alternatives A, B, and C, increased minimum flows would be provided at a relatively small cost with significant environmental benefits. Table 19 specifies the minimum flows that would be provided under alternatives A, B, and C. Minimum flows from tributary dams would cover continuously nearly 90 percent of the more than 200 river miles in tailwater regions exposed by hydroturbine operations under current policies. This would increase by about a third the total number of miles of large river habitat in the Tennessee Valley with improved flows to support healthier and more diverse aquatic communities.

Providing minimum flows from mainstream and tributary dams would involve a net annual loss of about $50,000 per year in the value of hydrogeneration. To minimize the effects on power generation, increased flows would be provided using turbine pulsing.

Use of turbine pulsing to achieve minimum flows would have two drawbacks. It could potentially affect the problems of slumping and wave erosion on banks in tailwater areas, leaving more archaeological sites exposed to looting and vandalism. If significant sites are adversely impacted by turbine pulsing, however, TVA will implement bank stabilization and protection techniques.

Turbine pulsing for minimum flows in tributary tailwaters also would increase the exposure of tailwater users to the risk of being trapped or swept away by rapidly rising waters in the first two to five miles before turbine pulses steady out. TVA already posts signs, distributes pamphlets, and advises callers requesting turbine operation schedules to warn tailwater users of this hazard. If minimum flows are increased through turbine pulsing, the adequacy of existing warning signs should be assessed and a special education effort should be undertaken to inform the public of the new operation and associated risks to tailwater users. This, combined with the effect of providing minimum flows, should improve awareness of rising and falling water levels.

Alternative A was rejected because DO levels higher than 4 mg/l are required to promote the growth and diversity of aquatic communities. There is no difference between alternatives A, B, and C in terms of minimum flows. All would provide the same flows, with the same benefits, and with the same costs. Alternatives B and C, however, would aerate releases to provide higher DO levels in reservoir tailwater areas. This would cost more, but would provide significantly greater benefits, particularly to aquatic life. These costs and benefits are discussed in detail below.

The higher DO target levels specified under alternatives B and C were selected because aquatic life would benefit significantly. Alternative A would provide aeration to raise DO concentrations to a target of 4 mg/l in the tailwaters of Watts Bar, Fort Loudoun, and 14 tributary dams. Alternatives B and C would provide aeration to raise DO levels to a target of 5 mg/l in the tailwaters of Watts Bar, Fort Loudoun, and four tributary dams with warm water releases, and to a target of 6 mg/l in the tailwaters of ten tributary dams with cold water releases.*

While providing 4 mg/l of DO would help some aquatic species survive, DO levels of 5 mg/l in warm water fisheries and 6 mg/l in cold water fisheries would promote the growth and diversity of aquatic communities. Improvements in benthic communities (e.g., increased species diversity and higher production) would occur with any increase in DO within the range of 0 to 7 mg/l, but achieving minimum levels of 5 mg/l in warm and 6 mg/l in cold tailwaters would allow development and protection of benthic communities characteristic of healthy warm and cold water stream systems. Mussels can survive at DO levels less than 5 mg/l for a short period of time, but require DO conditions in the range of 5 to 6 mg/l for growth. Improvement of DO levels to 5 or 6 mg/l appears to represent an optimum for obtaining benefits in growth, health, and species diversity of the fish community.

Restoration of DO levels to 5 mg/l (warm and cool water tailwaters) and 6 mg/l (cold water habitats) would permit the reestablishment of many benthic and fish species in areas which they formerly inhabited. As noted previously, combined with increased minimum flows, these DO levels would help to restore some 185 miles of tailwater habitat, increasing by about a third the number of miles of large river habitat in the Valley able to support healthy and diverse aquatic communities. Permanent improvements in flow and DO likely would lead to increased diversity, greater benthic and fish production, and improved yield. Some restored tailwater areas eventually could support reproducing populations of species now listed as endangered.

In combination with increased minimum flows, DO improvements would also address the impacts of current reservoir operations on tailwater fisheries. Significant increases in fishing activity, however, are dependent on other factors which are not affected by the alternatives (e.g., stocking a large number of desirable sport fish and providing improved access facilities). These improvements are not likely to occur except in isolated cases.

Wildlife would benefit as well, because of the increased habitat and productivity of tailwater areas. The principal beneficiaries are likely to be wading birds (e.g., herons which forage for small fish in shallow water) and furbearers (e.g., muskrat and raccoon which opportunistically feed on mussels, clams, and crayfish).

These benefits justify the added costs of the higher DO target levels. The initial capital and annual operating and maintenance costs for alternative A are about $33 million and $3 million, respectively. The initial capital and

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*None of the alternatives includes aeration for the seven lower dams on the Tennessee River because of concern about the feasibility of available aeration technology and excessive costs. DO problems at these dams are relatively infrequent and can be addressed in other ways (see Chapter 4).

annual operating and maintenance costs of alternative B, the cheapest of the two alternatives with higher DO target levels, are about $44 million and $4 million, respectively.

Alternative B is recommended over alternative C because the costs of pollution control would be born by polluters, and overall benefits to the environment would be greater. A basic principle of federal and state pollution control laws and regulations is that those responsible for pollution should bear the cost of pollution control--the "polluter pays" principle. If TVA adopted alternative C, it would aerate the releases from all 16 dams to provide 5 or 6 mg/l of dissolved oxygen in tailwater areas, including releases from eight dams which are impacted by pollution sources. This would add $10 million in capital costs and $1.5 million in annual operating costs, raising the total capital cost to $54 million and total operating cost to about $6 million. TVA would, in essence, be subsidizing the individual polluter by rectifying the effects of upstream pollution sources. This action also would remove some of the incentives for state governments to enforce or control these pollution sources.

Alternative B is recommended because state-mandated pollution controls in these eight tailwater areas will improve water quality in other upstream areas as well, thereby further relieving the burden of pollutants in the aquatic environment. TVA also would be aerating the releases of these eight dams to provide 4 mg/l dissolved oxygen, in addition to aerating to 5 or 6 mg/l at eight others not affected by upstream pollution sources, to counter the effects of its operations on water quality and aquatic life in the tailwater areas.

Reservoir Release Recommendations

The preferred release alternative is aimed at enhancing water quality and aquatic life in the Tennessee River system. No adverse environmental impacts are expected. However, in response to public comments received on the Draft Environmental Impact Statement, two commitments are proposed in conjunction with release improvements. These are listed below, followed by three other recommendations which would enhance the benefits resulting from the preferred release alternative.

> Tailwater Safety. Where minimum flows are provided through turbine pulsing, TVA should commit to take steps to inform tailwater users about the hazards associated with the new operation.

Explanation: As discussed in Chapter 5, the use of turbine pulsing to provide minimum flows in tributary tailwaters would increase the number of times during the week that hydroturbines are placed in operation. This would increase the exposure of tailwater users to the risk of being trapped or swept away by rapidly rising waters resulting from turbine discharges.

For years, TVA has posted signs, distributed pamphlets, and advised callers requesting turbine operation schedules to warn tailwater users of this hazard. The proposed commitment is recommended in keeping with this long-standing effort to ensure the safety of tailwater users.

Estimated annual cost: This commitment could be carried out within existing budget levels.

> Main River Monitoring. To avoid unforeseen impacts, TVA should commit to monitoring the effects of the proposed biweekly average summer flow requirements at mainstream dams on water quality and aquatic life.

Explanation: Proposed minimum flow requirements on the main Tennessee River call for biweekly average flows during the summer months. If power requirements were low, this allows for the possibility of one or more days of no discharge from a mainstream dam. During these low-flow periods, the capability of the river to assimilate wastes from pollution sources could be reduced significantly. Although these situations are expected to occur infrequently, TVA should commit to using its existing monitoring program to identify any unforeseen negative effects on water quality or aquatic life at key locations affected by pollution sources.

Estimated annual cost: Added costs to TVA's existing monitoring effort should be small.

> Implementing Reservoir Release Improvements. To accelerate the pace of release improvements and promote effective implementation, TVA should:
>
> o complete the implementation of the preferred alternative within a five-year period;
>
> o seek agreements with the states of Georgia, North Carolina, and Alabama similar to the current agreement with Tennessee for improvements of reservoir releases from TVA dams located in those states;
>
> o cooperate with the states to ensure that minimum flow criteria support the reasonable and necessary uses of individual rivers and streams as defined by the states; and
>
> o consider site-specific applications of aeration technology and biological monitoring of individual tailwaters in implementation decisions.

Explanation: As discussed previously in this report, TVA and the state of Tennessee agreed in 1987 to work cooperatively to improve water quality and aquatic life in the tailwaters of TVA dams. This agreement recognizes the need to provide minimum flows and aerate releases from the dams, and the need to control nonpoint sources of pollution that affect the tailwaters.

This agreement should serve as a model for similar agreements with the states of Georgia, North Carolina, and Alabama. More resources must be committed by both TVA and the states if the goals of the preferred reservoir release alternative are to be achieved before the turn of the century. To encourage state action, TVA should commit to installing aeration equipment at its dams within a five-year period.

These recommendations are based on an implementation strategy that has proven effective in experimental efforts on selected tailwaters conducted as part of TVA's Reservoir Release Improvement program--a cooperative effort to enhance tailwater management for multiple purposes. Under this strategy, detailed planning and implementation of improvements in minimum flows and dissolved oxygen levels are based on (1) the involvement of state agencies and other groups and (2) individual evaluations of the conditions and needs in each tailwater.

To implement alternative B, this approach should be expanded to recognize:

- the individual physical and biological characteristics of each tailwater;
- the feasibility and cost of applying available aeration technology at each dam;
- the effect of upstream pollution on dissolved oxygen in releases; and
- the objectives of state agencies, local governments, and other federal agencies for these tailwaters.

These factors will affect decisions such as:

- whether to use reregulation weirs to minimize turbine pulsing and/or recover more aquatic habitat in tailwaters;
- how to provide minimum flows from dams with one hydroturbine during a unit outage;
- what type of aquatic community to encourage in a tailwater;
- whether to require reductions in upstream pollution loads to reduce required aeration;
- how to manage the habitat of endangered species in a tailwater; and
- how to address the preservation of archaeological and historical sites that may be present in a tailwater.

This review of the needs of individual tailwaters also will affect decisions about whether to encourage recreational use of a tailwater, if and where to add stream access facilities, and what measures could better ensure the safety of tailwater users.

Estimated annual cost: This recommendation would affect the direction of TVA's water resource program, as well as the timing of capital improvements under the preferred reservoir release alternative. The focus, however, is on implementation strategy; no direct program costs would be involved.

<u>Developing Autoventing Turbine Technology.</u> TVA should pursue more vigorously the development of autoventing turbine technology for replacement hydroturbines.

Explanation: Minimum flow and dissolved oxygen improvements must be implemented in a cost-effective manner. In search of the most cost-effective alternatives, TVA has tested more methods and techniques for improving releases than any other public or private organization. TVA should continue this tradition, focusing particularly on autoventing turbine technology.

TVA reaeration research has already shown the potential of autoventing turbines to minimize common problems associated with aeration of turbine discharges (e.g., decreased turbine efficiency and capacity, turbine vibrations, cavitation erosion, lack of available space, and maintenance of operating equipment). This research should be accelerated to ensure that efficient autoventing turbines are available as TVA's aging hydroturbines require replacement over the next two decades. The average age of TVA's 107 hydropower units is 42 years. It is conceivable that hydroturbines could be replaced at the rate of six to eight per year for a period of several years before the end of the 1990s, presenting an excellent opportunity to switch to autoventing turbine technology.

Estimated annual cost: TVA currently is testing the feasibility of aerating turbines at Norris Dam. Details of subsequent turbine aeration research, and associated costs, can be better determined on completion of this pilot project.

<u>Financing Tailwater Releases for Whitewater Recreation.</u> TVA should explore opportunities for additional agreements to release flows for recreational floating, like its agreement with the state of Tennessee to provide releases from Ocoee No. 2 Dam, where ways can be found to compensate residential ratepayers for hydropower losses.

Explanation: Outfitters who take visitors on the Ocoee, Hiwassee, and Watauga rivers would like guaranteed releases from Ocoee No. 3 Dam and the Apalachia and Wilbur hydroplants, respectively. Local governments support their requests, viewing whitewater recreation as a part of their economic future, like lake recreation and tourism.

The magnitude of the flows requested are much larger than needed for improvements in water quality and aquatic life. However, tailwater releases for whitewater recreation at the above projects could be provided without significant adverse effects to other reservoir system benefits, except for hydropower production. (The effects on hydropower are discussed below, under "Estimated annual cost.") There is no conflict with holding pool levels higher at upstream reservoirs at any of these projects because flows that would have been discharged anyway are released through spillways or from turbines at the times preferred for recreational floating.

To make such releases possible at the Ocoee No. 2 project, the Congress made a one-time appropriation to compensate the TVA power system for lost generation. The appropriation is being repaid to the U.S. Treasury from user fees. This serves as one model for the types of financing arrangements that could be developed.

Estimated annual cost: Preliminary estimates of the cost to TVA's power system of providing releases from Ocoee No. 3 Dam and the Apalachia and Wilbur powerhouses are given in table 31. Releases from Ocoee No. 3 are much more expensive than releases from the other two projects because the Ocoee No. 3 releases bypass the turbines. The cost of releases from Apalachia and Wilbur reflect only the costs of shifting hydropower production from times of peak power demand during the week to off-peak periods.

Table 31
Cost of Hydropower Losses
For Selected Recreational Floating Options

Dam	Point of Release	Estimated Average Annual Cost ($m)
Ocoee No. 3	Dam	1.0
Apalachia	Powerhouse	0.1
Wilbur	Powerhouse	0.01

Notes:
1. Releases are scheduled for 6 to 10 hours per day during weekdays and weekends during June, July, and August, and on weekends of other months from March or April to October or November.
2. Power costs are estimates only and are intended to show only the order of magnitude of lost hydropower value.

Rationale for Preferred Lake Level Alternative

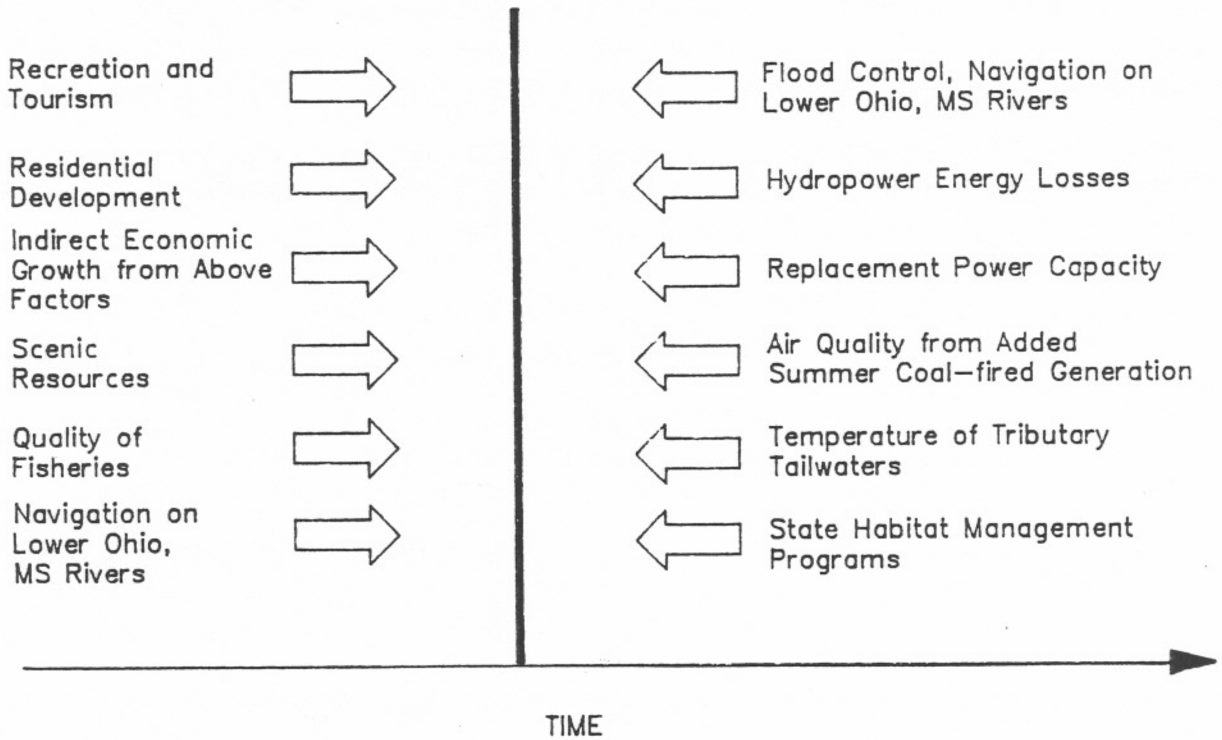
A total of eight lake level alternatives were evaluated, as described in Chapter 4. Under the no action alternative, TVA would continue to follow current reservoir operating policies, gradually filling ten tributary lakes through the spring and beginning rapid drawdown to January 1 flood control levels after Memorial Day. Under the three alternatives in which the ten tributary reservoirs are treated uniformly, TVA would fill tributary reservoirs more aggressively in the spring and would delay unrestricted drawdown until different times. Rapid drawdown to flood control levels would begin on August 1 under alternative 1, on Labor Day under alternative 2, and on October 31 under alternative 3.

Under the other four alternatives, unrestricted drawdown to flood control levels would begin on August 1 for most tributary reservoirs, but would be delayed until October 1 on Knoxville area reservoirs under alternative 1A, on Tri-Cities area reservoirs under alternative 1B, on Fontana reservoir under alternative 1C, and on Hiwassee basin reservoirs under alternative 1D.

Alternative 1 (delaying unrestricted drawdown on all ten reservoirs until August 1) is recommended primarily because it would improve recreation and economic development in tributary lake areas without significantly affecting environmental quality or other reservoir system benefits, particularly hydropower production, flood control, and navigation on the lower Ohio and Mississippi rivers.

Figure 18 shows how different forces in the natural and socioeconomic environment affect the optimal timing of reservoir drawdown. The rationale for selecting alternative 1 is discussed in detail below.

Figure 18
Forces Acting on the Timing of Reservoir Drawdown



<u>The no action alternative is not recommended primarily because of new demands on the Tennessee River and reservoir system.</u> There is evidence from across the Nation and within the Tennessee Valley that the public wants more from reservoir operations than the traditional benefits of navigation, flood control, or power production.

The growing importance of recreation and environmental considerations is reflected in national legislative trends. Private hydroplant owners must negotiate with state and federal environmental and recreation agencies to reach agreement on acceptable operating policies to relicense projects with the Federal Energy Regulatory Commission. A plan developed by the Northwest

Power Planning Council requires special water releases and the construction of special facilities to allow fish to pass around dams on the Columbia River during spawning.

In the Tennessee Valley, lake levels for recreation has been a long-standing issue. Comments received during the scoping process for this study and during public review of the Draft EIS underscore the importance of this concern. Residents and community leaders want high quality recreation on the region's lakes. In tributary counties plagued by low income and high unemployment levels, many view recreation, tourism, and second-home development as their economic salvation.

<u>Alternatives 1A, 2, and 3 are not recommended because of their effects on other system operating purposes and on environmental quality.</u>

Impacts on flood control on the lower Ohio and Mississippi rivers preclude the choice of alternative 3 and weigh against the choice of alternatives 2 and 1A. Delaying unrestricted drawdown of all ten tributary reservoirs until October 31 would interfere with flood control operations by the U.S. Army Corps of Engineers on the lower Ohio and Mississippi rivers. Stored flood water could rise to, and possibly exceed, TVA's easement levels in Kentucky Lake during such operations, and could increase flooding on the lower Ohio and Mississippi. Flood control impacts also are possible under alternatives 2 (Labor Day drawdown of all ten reservoirs) and 1A (October 1 drawdown of Knoxville area reservoirs; August 1 drawdown of others), but are not as great a concern.

Impacts on navigation on the lower Ohio and Mississippi rivers preclude the choice of alternative 3 and weigh against the choice of alternative 1A. Under the October 31 alternative, flow from the Tennessee and Cumberland rivers would be decreased during September and October before tributary lakes are lowered. This would reduce water depths for commercial navigation on the lower Ohio and Mississippi during the months when low flow conditions are most likely, significantly impairing navigation on those rivers especially during a dry year. Similar effects would occur during September under alternative 1A.

Power costs preclude the choice of either alternatives 2 or 3, and weigh against the choice of alternative 1A. Delaying unrestricted drawdown on all ten tributary reservoirs until Labor Day or beyond would shift over 1.3 billion kilowatthours from the spring and summer into the post-Labor Day period. This would require the eventual addition of 750 megawatts of capacity, at an initial capital cost of $560 million, to assure the reliability of the overall power system during the summer peak season. If this additional capacity were not built, the capability of the power system to meet the peak load during the summer would be reduced, leading to a greater probability of power being curtailed or voltage being reduced in local areas when demand exceeds supply. Annual losses in the value of hydropower energy, ranging from $16 to $25 million, also would result.

Alternative 1A would require a 100-megawatt capacity addition and involve annual losses in the value of hydropower energy of about $6 million. These costs are substantially less than under alternatives 2 and 3 because unrestricted drawdown would be delayed until October 1 on only three reservoirs (Norris, Douglas, and Cherokee), but much higher than the costs associated with alternatives 1 and 1B through 1D.

Alternatives 2 and 3 also are precluded by environmental considerations. Increases in air emissions during the summer from increased coal-fired generation would impact air quality. For alternative 3, the average increase in emissions would be about 6 percent of current coal-fired emissions in the summer, ranging as high as 8 to 10 percent in a worst-case year. Because dispersion conditions are worse in the summer and pollutant transport is slower, small increases could occur in acid deposition, ambient air pollutant concentrations, and the burden of pollutants in the environment. The annual average increase in emissions of air pollutants and carbon dioxide from extending summer pool levels through the end of October is estimated to be about one percent of current coal-fired plant emissions; the highest expected annual average increase would be about 2 percent. Alternative 2 would have a similar effect on air quality, although slightly lower increases in emissions would be expected.

Alternatives 2 and 3 also could have a significant effect on water temperatures in tailwater areas. By the end of the summer, the temperatures of releases during normal and dry years for these alternatives could vary from 5 or 6°C (9 or 11°F) to 9°C (16°F) colder than under existing policies. In wet years, the effect would be less significant. The net result would be wider variation in release temperatures from year to year. Where cold water fisheries currently exist, growth rates could be lowered significantly or increased depending upon whether temperatures are already at or above the range for optimal growth. Also, because of the flat target elevations specified under alternatives 2 and 3, current marginal conditions for warm water fisheries below Cherokee and Douglas dams could deteriorate significantly and be more difficult to manage.

In addition, alternatives 2 and 3 would affect efforts by state fisheries management agencies to grow grass cover in drawdown zones for the next year's newly spawned fish. Continued seeding would depend on the availability of backlying land. Wildlife management activities in the Rankin Bottoms area on Douglas Lake also would be affected adversely. Higher lake levels resulting from flat recreation targets under these alternatives would cover crops planted to provide forage and habitat in fall months for waterfowl and migrant birds.

<u>Alternatives 1, 1B, 1C, and 1D have less effect on other reservoir system benefits than alternatives 1A, 2, and 3.</u>

Alternatives 1, 1B, 1C, and 1D have less effect on hydropower production. For alternative 1, a significant percentage of the shifted energy can still be used during the last half of the summer when the highest weekly power demands are most likely to occur. About 240 million kilowatthours of hydropower generation are shifted into the late summer, while only about 310 million kilowatthours are shifted into the period between Labor Day and January 1. With the flexible implementation strategy outlined in Chapter 4, this allows the power system to maintain its current level of reliability without expensive capacity additions. Annual losses in the value of hydropower energy also are considerably less (about $2 million, compared to $6 million under alternative 1A, $16 million under alternative 2, and $25 million under alternative 3).

Power costs also are reduced under alternatives 1B, 1C, and 1D. However, the cost of replacement capacity weighs against the choice of 1B and 1C ($7 million and $22 million, respectively), and the cost of changes in operation at John Sevier Fossil Plant add to the power costs under 1B. Alternative 1D would not require construction of additional capacity; annual losses in the value of hydropower energy would be about $3 million.

The negative effects of alternatives 1, 1B, 1C, and 1D on water quality and aquatic communities would not be significant. The temperature of releases from tributary and mainstream dams would be reduced under these alternatives, but not enough to have a significant effect on tailwater fisheries. Moreover, the temperature effects would be tempered by providing higher minimum flows.

Delaying unrestricted drawdown of all tributary lakes until August 1, or delaying unrestricted drawdown until August 1 on some lakes and until October 1 on others, would reduce flow during part of the summer on mainstream reservoirs. This would affect dissolved oxygen (DO) levels, much like DO levels are affected by low flows during dry years. Reduced DO levels on the main river, however, would be tempered by providing minimum flows and aeration at Fort Loudoun and Watts Bar dams under release alternative B.

In tributary reservoirs, higher pool levels and lower releases would result in both positive and negative effects on reservoir water quality (see Chapter 5). However, alternatives 1, 1B, 1C, and 1D are unlikely to produce significant overall change from that experienced under existing policies.

The environmental effects of changes in the use of thermal generating units would be minor under alternatives 1, 1B, 1C, and 1D. This is because more hydropower would be generated during the late summer under these alternatives than under alternatives 1A, 2 and 3.

Navigation and flood control on the lower Ohio and Mississippi rivers would not be impacted significantly under alternatives 1, 1B, 1C, and 1D. As noted below, these alternatives would actually provide navigation benefits during dry years.

Alternatives 1, 1B, 1C, and 1D would result in significant benefits.

These alternatives would increase recreation visitation and use of existing commercial and public recreation facilities (e.g., launching ramps, docks, and boat slips). As noted in Chapter 5, a 21-percent increase in recreation visitation is projected under the August 1 alternative, 23 percent under alternative 1B (delayed drawdown on Tri-Cities area reservoirs), 22 percent under alternative 1C (delayed drawdown on Fontana), and 24 percent under alternative 1D (delayed drawdown on Hiwassee basin reservoirs).

Economic growth around the ten tributary reservoirs due to recreation, tourism, and second home development would be less constrained by summer drawdown. This is important because about half of the counties near eastern tributary reservoirs are among the 50 poorest counties in the Tennessee Valley, based on per capita income and percentage of population below the poverty level.

Determining the effect of improved summer lake levels on economic growth is difficult, however, and has not been attempted in quantitative terms. This is because summer lake levels are only one of several factors affecting economic growth. Equally important, if not more important, are such factors as the proximity of reservoirs to major population centers, transportation access to these reservoirs, and public and private investments in recreation and tourism facilities.

Local governments are expected to be able to manage the growth in their communities that may result from any of the lake level alternatives. No adverse effects on their finances or service levels are anticipated.

The scenic quality of tributary lakes during the summer would be significantly improved. TVA's tributary reservoirs are located in areas known for mountain vistas and seasonal colors. Mudflats and dry coves exposed during summer drawdown detract from the visual quality of these reservoirs. About 36 percent of the average summer drawdown zone would be covered by keeping lake levels higher through August 1; slightly more of the drawdown zone would be covered under alternatives 1B, 1C, and 1D. The ten tributary reservoirs affected by the alternatives could be filled to the top of the unvegetated zone in about 20 to 30 percent of the years for all alternatives, compared to about 10 to 20 percent of the years under current operations. Improvements in visual quality should be proportional to the length of time pools are extended. This, however, is a subjective judgment.

The quality of reservoir fisheries would be significantly improved. Under existing policies, late spring/early summer drawdowns will continue to expose shallow spawning areas and reduce the amount of flooded terrestrial vegetation which produces food and provides shelter for young fish. Holding pool levels higher during the spring and early summer would provide more food and shelter for young fish and would increase populations of many sport and commercial species. Maintaining higher tributary pool levels for longer in the growing season could benefit benthic and fish stocks by encouraging the establishment of aquatic plant (macrophyte) growth. Extensive macrophyte growth, which is unlikely, could interfere with some recreation uses and produce high populations of mosquitoes. This could lead to increased control of such growth through the use of herbicides and other methods.

Navigation would benefit during dry years on the lower Ohio and Mississippi rivers. Flows from the Tennessee and Cumberland rivers during September and October would be increased compared to existing policies. The resulting increased water depth in the lower Ohio and Mississippi rivers would aid commercial navigation during this low flow period on those rivers, particularly during a dry year.

<u>Cost and equity considerations point to the choice of alternative 1.</u>

Alternative 1 has the least effect on hydropower production. This is because rapid drawdown to January flood control levels would begin on August 1 on all ten tributary lakes. There are no capacity costs associated with this alternative; the annual energy cost would be about $2 million.

Table 32 shows the added costs, above the cost of the August 1 alternative, that are associated with alternatives 1B, 1C, and 1D. Alternative 1D (October 1 drawdown on Hiwassee basin lakes) is the cheapest of these alternatives, involving an additional $1 million in annual energy costs. Alternative 1C (October 1 drawdown on Fontana) also would add $1 million in annual energy costs, plus $22 million in replacement capacity to maintain the reliability of the power system. Alternative 1B (October 1 drawdown on South Holston and Watauga) would cost about $7 million more in annual costs (energy losses and changes at John Sevier Fossil Plant, which relies on these reservoirs for cooling water), plus $7 million in capital costs for replacement capacity.

Table 32 also shows the incremental costs associated with various combinations of alternatives 1B, 1C, and 1D. While additional review is needed in some cases, these combinations could be implemented without substantial impacts on the environment and other system operating purposes. As shown, the cost of these combinations is not the simple addition of the cost of the individual alternatives. As the date of unrestricted drawdown is delayed on more reservoirs, the capability to produce hydropower to meet summer power needs is constrained disproportionately, and the power costs increase at a greater rate.

Table 32
Additional Power Costs for
Improved Lake Levels Until October 1[1]

Alternative	Incremental Power Cost[2]		
	Annual Energy Cost ($m)	Required Capacity Addition (MW)	Initial Capital Cost ($m)
1D (Hiwassee Basin)	1	0	0
1C (Fontana)	1	30	22
1C + 1D (Fontana, Hiwassee Basin)[3]	2	50	37
1B (Tri-Cities)	7	10	7
1B + 1D (Tri-Cities, Hiwassee Basin)[3]	8	20	15
1B + 1C (Tri-Cities, Fontana)[3]	8	60	44

Notes:
1. Unrestricted drawdown on reservoirs in each group would be delayed until October 1 using sloping recreation target levels (table 22); drawdown on other reservoirs begins on August 1.
2. Assumes alternative 1 (August 1 drawdown of all 10 tributary reservoirs) as base case.
3. Requires additional review to better identify environmental and operational impacts.

Alternative 1 would benefit all tributary areas equally. TVA manages tributary lakes as uniformly as possible so that system benefits are distributed fairly. Alternatives 1B, 1C, and 1D, which would extend pool levels on one group of lakes two months longer than on other tributary lakes, would be inconsistent with this practice. This could be viewed by some as preferential treatment and could result in strong opposition from people living around lakes subject to earlier drawdown.

Other factors also support the choice of alternative 1.

Alternative 1 would help protect archaeological sites and have a controllable effect on historical structures. Leaving tributary lake levels higher during the summer and fall periods would alleviate certain looting problems because some archaeological sites located below the maximum shoreline contour would be covered by water for an extended period. Increased shoreline development resulting from alternative 1, however, could affect historic structures and small towns with historical districts situated in the areas of development. If development occurs on TVA land as a result of the lake level alternatives, or developers request special access through TVA lands, TVA must evaluate the effects of development on historic properties on or adjacent to TVA lands under the provisions of the National Historic Preservation Act. Where development occurs on private lands, there is no federal procedure for review and protection of historic properties. States and counties may have historic zoning and other protection statutes.

The impacts of additional recreational use on tributary reservoirs due to alternative 1 are expected to be minor. Small increases are expected in soil erosion due to wave wash from boats, in nuisance problems related to boating, and in lake use conflicts related to recreation.

Alternative 1 would have a positive effect on wildlife populations. In general, wildlife populations associated with the Tennessee River and its tributaries have adapted to how the reservoir system is now operated. Lake level alternatives are likely to have the positive effect of increasing foraging area and prey production.

The potential cumulative impacts of shoreline development under alternative 1 are not expected to be significantly different than under current policy, and can be forestalled by the cooperative efforts of federal, state, and local governments. If controls are not implemented, some lakes could experience negative effects of shoreline development in local areas where development occurs. These impacts include nonpoint source pollution from soil erosion and user activities on developed shoreline lands, and loss of aquatic and riparian habitat for fish and wildlife. However, staff judgment is that the cumulative impact of shoreline development will not reach significant proportions any earlier under the lake level alternatives than it will given the existing rate of development.

Potential cumulative effects of shoreline development can be minimized through state or local government controls (e.g., subdivision development standards, nonpoint source pollution standards, and required use of Best Management Practices), combined with TVA and other federal agency enforcement of public shoreline use and development policies.

Lake Level Recommendations

Recommended below are additional measures TVA can undertake to influence the location and type of shoreline development occuring around tributary lakes. These include a commitment to monitor the cumulative effects of this development and several improvements in the management of TVA reservoir lands.

<u>Monitoring Shoreline Development.</u> If TVA implements the proposed lake level alternative, it should commit to monitoring shoreline development trends so that problems can be identified in time to implement effective remedial action.

Explanation: The ten tributary lakes affected by the August 1 lake level alternative will become more attractive for shoreline development. Whether this attractiveness results in increased development will depend on other factors, such as population, land ownership, and accessibility from population centers. It is difficult to determine whether the cumulative impact of increased shoreline development will reach significant proportions earlier as a result of the recommended alternative than it would given existing rates of development. Staff judgment is that the added effects will not significantly accelerate problems related to cumulative impact. However, the proposed commitment is recommended because of the public concern expressed over this issue. It should give added assurance that problems can be identified early enough to be addressed effectively, and help to ensure a future balance between developing the shoreline to promote economic growth and protecting environmentally important uses of this resource.

Estimated annual cost: The cumulative impact of shoreline development on tributary lakes could be monitored as part of TVA's existing land and water resource programs. Added costs to these programs would be small. Implementing effective remedial actions, however, would likely require cooperation from all levels of government.

<u>Promoting a Balanced Use of Reservoir Shorelines through TVA Land Management.</u> To provide a model for the management of non-TVA reservoir lands, TVA should:

- o accelerate the development of land management plans for tributary reservoirs, completing plans for Melton Hill, Norris, Cherokee, Chatuge, and Tellico by 1996;
- o improve the data base for reservoir lands management by collecting additional information (on shoreline development and erosion, for example) and by updating it more frequently;
- o extend the planning process to include "marginal strip" land (the generally narrow strip of land at the water's edge, abutting private property, which is owned and used by TVA); and
- o place higher management and budget priority on implementing reservoir land management plans.

Explanation: As discussed above, it is difficult to determine the extent to which the proposed lake level improvements would result in increased shoreline development because of the importance of economic and demographic factors (e.g., population growth, land ownership, and accessibility from population centers). However, public comments and available data on shoreline structures and population confirm that shoreline development around TVA reservoirs is increasing even without extended lake levels. This development is becoming a source of conflict and management concern, particularly on those lakes where development is increasing at the greatest rate.

There is little TVA can do to influence the location, nature, and rate of this development. As discussed in Chapter 4, several alternatives were considered--additional regulatory authority, the doctrine of riparian water rights, and certain deed provisions on transferred lands--but these alternatives were not evaluated in detail because of concerns about their feasibility or effectiveness.

TVA does have control over activities on its own lands, however, and can exert an influence over shoreline development on non-TVA reservoir lands by the example it sets. As noted earlier, TVA owns about 250,000 acres of reservoir land above summer pool, including about 2750 miles of shoreline. This land, like other undeveloped public land, is being sought by industrial and commercial interests and is being subjected to intense recreational pressure by residential growth around the reservoir system. This makes reservoir stewardship and shoreland protection more difficult, but presents an opportunity for TVA to demonstrate effective land management. How well TVA takes advantage of this opportunity will affect its credibility in working with others to control development on private and other public reservoir lands. TVA can be more effective in encouraging other federal agencies and state and local governments to implement shoreline development controls if it is recognized as a model land manager.

TVA is planning to take several steps to address problems related to increased development pressure. For example, more attention will be focused on preventing and resolving encroachments of TVA land rights and violations of Section 26a, including better marking of property boundaries and increased monitoring of activities on TVA reservoir land. A land stewardship education campaign is being directed at landholders and other lake users.

In the course of evaluating alternatives for this study, other actions were identified that could complement these efforts. The most critical is committing additional resources to the tributary lands planning process. Under current budget constraints, planning for tributary reservoirs will not begin until 1991. At most, one plan will be completed each year, extending the tributary lands planning effort well past the year 2000. To help avoid the negative impacts of shoreline development, this schedule should be accelerated. Priority should be placed on Melton Hill, Norris, Cherokee, Chatuge, and Tellico for a variety of reasons--because of the amount of land owned by TVA, the extent of current development pressure, and contract obligations.

Accelerating TVA's tributary lands planning effort also would result in earlier completion of an environmental data base on reservoir shorelines. This would help TVA evaluate specific shoreline development requests and facilitate future policy evaluations. It also would enable TVA to provide timely information important to the land management decisions of others. As information is collected to support the land planning process, consideration should be given to expanding the data base to include residential development, shoreline erosion, and other environmental considerations. Resources also should be allocated to ensure that critical data is updated more frequently.

Including marginal strip land in TVA's land management planning process would promote a balanced use of this property, as well as assure that the multiple uses of the reservoir are preserved. It also would increase the opportunities for public and stakeholder involvement in decisions concerning shoreline use.

Finally, as reservoir land management plans are completed, the resources must be provided for implementation (i.e., resource protection, program delivery, and demonstrations). TVA also must consistently consider the plans in responding to shoreline development proposals.

Estimated annual cost: An annual increase of about $300,000 in the current budget for reservoir land planning would be required to complete plans on key reservoirs (Melton Hill, Norris, Cherokee, Chatuge, and Tellico) by 1996.

Other Recommendations

Three additional recommendations resulted from concerns raised by participants during the scoping process for this study. Comments about the need for regional cooperation and broader public involvement in water resource decisionmaking led to a recommendation for improving communication with lake users. A proposal by navigation interests to raise winter levels in mainstream reservoirs led to a recommendation that TVA reassert leadership in navigation development. Questions about whether the study is correct in assuming the continuation of current weather patterns led to a recommendation for monitoring and planning for the effects of climate change on reservoir operations.

These recommendations are explained below.

Improving Communication with Lake Users. To ensure that TVA's lake and river operations respond to the needs and desires of lake users, TVA should:

- improve communication regarding routine reservoir operations;
- work to increase public understanding of TVA lake and river operations and land management policies;
- provide opportunities for public input to river system planning and management; and
- work more closely with other government agencies responsible for water resources, particularly the seven Valley States, to address issues of mutual concern.

Explanation: This recommendation responds to growing public interest in reservoir planning and operation and to the need expressed during the public review process for improved intergovernmental coordination in addressing regional water resource issues.

Options related to public involvement, public education, or public relations were identified by every QUEST group. Establishing user advisory panels and better educating the public concerning the operation of the reservoir system were repeatedly listed among the options participants would most like to see TVA pursue. Proponents of these actions cited numerous benefits: identification of a broader range of options, a better understanding of the tradeoffs involved in water resource management, reduced conflict, and a better informed and more active citizenry.

Lake users are one of TVA's largest and most important customer groups and yet, as a general rule, they have no organized means of communicating with TVA. To remedy this situation, TVA should take steps to: (1) improve communication regarding routine reservoir operations, (2) increase public understanding of TVA lake and river operations, and (3) provide a means for channeling public communication back to TVA.

The TVA Board already has approved several actions to accomplish these goals, including lake recreation maps which will be made available free to the public; an 800-number voice response telephone system which will provide up-to-date information about streamflows, lake levels, and generation schedules; and a pilot newsletter for targeted tributary lakes.

Other activities which TVA could undertake to accomplish these objectives are listed below.

- o Develop a set of clear measures to monitor and report to the public on the benefits and performance of the river system.

- o Issue bulletins at the beginning and end of the spring fill period and during the summer explaining current and expected reservoir levels.

- o Identify special drawdown operations earlier and provide lake users with more advance notice.

- o Use speeches and develop videos to explain TVA's reservoir operating policies to lake users.

In addition to improving communication with lake users, TVA also should work to promote increased regional cooperation in water resource decision making. This is important because jurisdiction over water resources in the Tennessee Valley resides with many different government agencies. Water resource issues can be addressed more effectively if these agencies work together to achieve mutual objectives. This will require cooperation and interaction at the executive level in setting program direction and allocating resources.

As a start, an annual meeting is recommended between the TVA Board and the governors of the seven Valley states to exchange information on water resource policies and plans. TVA should host this meeting and set the stage for open communication by inviting comment on its lake and river operating plans and objectives.

Estimated annual cost: This recommendation could be implemented within existing budget levels by shifting program direction and reallocating staff time.

Reasserting Leadership in Navigation Development. Recognizing the importance of navigation to the region's economy and TVA's leadership responsibility under the TVA Act, TVA's agenda for navigation development in the 1990s should include:

- seeking adequate funding from Congress for capital additions and improvements to the Tennessee River waterway and existing locks to improve lock operating efficiency and the safe movement of barge traffic through the system;
- supporting the ongoing feasibility study of the U.S. Army Corps of Engineers (USACE) for a new main lock at Kentucky Dam and working with the USACE to implement the most effective procedures for funding final engineering design and construction;
- preparing the feasibility study for upgrading the navigation locks on the upper Tennessee River, and seeking funding from Congress and maintaining responsibility for designing and constructing the new main locks if authorized; and
- seeking more funding from Congress to enhance navigation maintenance activities.

Explanation: TVA played a leadership role in water transportation on the Tennessee River until the late 1970s when budget priorities resulted in less emphasis on navigation program activities. The last economic analysis of a new lock performed by TVA was in 1974 at Pickwick Landing Dam. Consequently, the U.S. Army Corps of Engineers began funding navigation additions and improvements as well as major lock repair projects on the Tennessee River. In addition, the Corps intensified studies for a new main lock at Kentucky Dam to resolve navigation problems on the lower Cumberland River, and initiated studies for new main locks at Chickamauga and Watts Bar dams. (In May 1990, TVA and the Corps mutually agreed that TVA should assume the leadership role in completing the feasibility studies for the new main locks at Chickamauga and Watts Bar dams.)

This decline in TVA support for navigation should be reversed for two reasons. First, TVA has a statutory responsibility for navigation activities on the Tennessee River. If TVA were to relinquish its leadership role in navigation, it could lead to further erosion of TVA's authority and responsibility for managing the Valley's water resources.

Second, resuming a leadership role in the development of the Tennessee River waterway is essential to TVA's economic development mission. A viable water transportation system yields benefits to consumers generally, to communities along the waterway, and to the Nation.

The public interest is benefited by the controlling influence low waterway rates have on rail and other freight rates. By lowering freight rates, a viable water transportation system helps provide purchasers and consumers the benefit of lower prices. Communities along the waterway benefit from industrial development based on water transportation. National benefits result from opening up market opportunities by reducing transportation costs for the indigenous natural resources of different geographic regions (coal and wood products, in the case of the Tennessee Valley).

Additional funding for navigation improvements on the Tennessee River is justified by these benefits, and by the fact that the Tennessee River does not get its share of the federal dollar spent on capital projects for navigation improvements. Shippers using the Tennessee River pay a fuel tax to the Inland Waterways Trust Fund. This fund is allocated to help pay for the costs of new construction projects to improve the Nation's inland waterways. Thus far, none of these funds (which have been allocated through most of the next decade) have been earmarked for improvements on the Tennessee River.

Estimated annual cost: The cost of implementing the recommended actions already has been factored into TVA's appropriated budget plan.

<u>Monitoring and Planning for the Effects of Climate Change on Reservoir Operations.</u> To improve its ability to detect and to adapt reservoir system operations to extended changes in regional weather patterns, TVA should:

- improve the collection and analysis of weather-related data to support the identification of long-range trends and the detection of temporary departures from normal weather patterns, such as extended drought conditions;
- continue to analyze the impacts of potential long-term changes in Valley climate, particularly temperatures and rainfall, on TVA activities;
- determine flow and temperature thresholds beyond which changes would have to be made in system operation; and
- develop contingency plans as needed to adapt to likely departures from the historical climatic record.

Explanation: The historical climatic record has been used in this study to analyze changes in reservoir system operations under the assumption that it adequately describes future rainfall and runoff patterns. There is evidence to suggest, however, that this may not be the case.

While researchers disagree about the timing, characteristics, and magnitude of future changes in temperatures and rainfall, there is consensus that changes are inevitable. For the Valley, most predict warmer temperatures but impacts on precipitation and runoff are highly uncertain.

The U.S. Environmental Protection Agency (EPA) selected three global climate models to provide a basis for regional and national impact assessments of sensitivity to global climate change. One predicts increased precipitation for the Southeast; one predicts a decrease, particularly in the summer; and one predicts little change on an annual basis but with a seasonal shift to lower spring rains and higher summer and fall precipitation.

TVA participated in the EPA study, analyzing the sensitivity of the TVA reservoir system to two climate change scenarios. Both, TVA concluded, would impact the ability of the TVA reservoir system to meet current project multipurposes and would necessitate a reevaluation of present operating philosophy and priorities.

The wetter, warmer scenario increased water availability for power production, recreation, minimum flow requirements, and water supplies, but significantly increased Valley flooding and raised dam and nuclear plant safety issues. The drier, warmer scenario decreased flood potential, but reduced water availability for power generation, recreation, domestic and commercial consumption, agricultural irrigation, water quality, and environmental/safety compliance at nuclear and fossil plants.

The magnitude of the potential impacts, combined with the huge investment in TVA's reservoir system and the importance of the benefits it provides, demand that more attention be paid to hydrologic and climatic variables. Given the uncertainty about the direction of local changes, it is premature to suggest changes in reservoir guide curves or structural changes to the system to respond to an altered climate. However, increased research on the system impacts of potential changes in temperature, rainfall, and other climatic variables, coupled with improved long-range planning, should help TVA improve its flexibility to deal with future changes regardless of their direction and magnitude.

Estimated annual cost: This recommendation could be implemented by shifting program priorities and reallocating staff time and by cooperative efforts with other federal agencies having climate change research funds.

Chapter 7

Funding

Notwithstanding possible legal limitations, there are three principal options for funding release and lake level improvements. Federal taxpayers could bear the costs through the use of Congressional appropriations, Valley power consumers could bear the costs through the use of power revenues, or both groups could share the costs through the use of a combination of appropriated and power funding.

Based on consideration of these options, two funding recommendations are discussed in this chapter:

1. Power revenues should be used to pay for release improvements.

2. Appropriated funds should be used to pay for lake level improvements.

The combined funding option, which TVA uses to fund other reservoir system costs, is described first as a basis for evaluating these recommendations.

User fees for lake level improvements are discussed at the end of this chapter. These are not recommended, however, because they would be difficult to administer, given the diversity and geographical dispersion of beneficiaries, and because they probably would not be adequate to cover the full costs of the improvements.

Current Funding Strategy for TVA Reservoir System Costs

A combination of appropriated funds and power revenues currently is used to fund reservoir system capital and operating expenses, as well as costs associated with TVA's Reservoir Releases Improvements program (discussed in Chapter 2).

Capital cost allocations are calculated by TVA at the time a dam is constructed. These allocations must be approved by the President and cannot be changed except by Congressional legislation. Formulas vary by project. Typically, however, about 58 percent of reservoir system capital costs are paid out of appropriations and about 42 percent are power-funded.

Funding responsibility for reservoir system operating costs is determined using a method called MRO (multipurpose reservoir operations) cost allocation. Using MRO formulas, operating and maintenance costs are distributed between federal taxpayers and Valley power consumers according to the estimated benefits each receives. Where a single purpose is served (e.g., power generation or navigation), costs are allocated entirely to that program. Where more than one purpose is served, costs are allocated among TVA's power and nonpower programs based on each program's share of total estimated benefits.

Allocation of multipurpose operating and maintenance costs are periodically reviewed and updated by TVA to allow for changes in the distribution of benefits. Currently, about 74 percent of MRO operating costs are funded by appropriations and about 26 percent are funded by power.

Recommended Funding Strategy for Release Improvements

As discussed in Chapter 4, the costs associated with the preferred release alternative are related to raising dissolved oxygen (DO) concentrations in water released through 16 TVA dams. A capital expenditure of about $44 million would be required to install aeration equipment with an annual expense of about $4 million to operate and maintain it. In addition, providing higher minimum flows would reduce the value of the energy produced at TVA dams by about $50,000 a year.

It is recommended that TVA power funds be used to pay these costs because the proposed release improvements would mitigate the environmental effects which result from the way TVA dams were designed to produce hydropower--particularly, the effects of low DO levels in tailwater areas associated with turbine releases in late summer and fall. As discussed in Chapter 3, hydroturbines at TVA dams were designed with low level intakes to maximize generating potential, and allow the hydroturbines to operate during the winter season when lake levels are kept low to provide flood storage capacity, or during other times of the year under drought conditions.

If hydrogeneration were not a concern, water could be released through spillways or other outlets at minimal cost and aerated either by the passage of the water through the outlet structure or by withdrawal from the upper layer of the reservoir where DO levels are higher. This would mitigate the problem of low DO in tailwater areas associated with hydropower generation, but the cost in terms of displaced power generation would be high. The proposed release improvements represent a more economical way to mitigate the effects of hydrogeneration and a way which avoids the waste of water power.

Because low DO releases result from the design and operation of TVA dams for hydropower purposes, the cost of mitigating the adverse environmental effects associated with those releases (e.g., low DO, low flows) can appropriately be viewed as an ordinary business expense of the power system. In addition, the recommended improvements in water quality and aquatic habitat would benefit the region's economy by improving the overall quality of life and the attractiveness of the Valley. Any improvement in the region's economy is good for TVA and its power program.

Other funding options for release improvements were rejected for the reasons described above. The proposed improvements are an appropriate power program investment in the health of the region's water resources--an important factor in sustaining the long term growth of the region.

Recommended Funding Strategy for Lake Level Improvements

As discussed in Chapter 5, the preferred lake level alternative (filling tributary lakes more aggressively and extending recreational pool levels until August 1 on ten tributary lakes) would reduce the value of the hydropower produced at TVA dams by about $2 million annually. This value would vary widely from year to year depending on rainfall--from a $20 million increase to a $9 million reduction in operating costs.

Those who commented on the Draft EIS disagreed on the legality of using power revenues to fund lake level improvements. Some argued that the TVA Act permits the use of water for social and economic development, including environmental quality, as well for power. Distributors of TVA power took a different view, arguing that using power funds to pay for lake level improvements or dividing the costs between power revenues and appropriations would violate Section 9a of the TVA Act. As noted in Chapter 2, Section 9a requires that the Tennessee River system be operated primarily to promote navigation and flood control and, to the extent consistent with these purposes, for power production.

Legal issues aside, the cost of lake level improvements should be paid out of Congressional appropriations because the primary purpose served by the improvements is recreation and economic development in tributary lake areas. Congressional appropriations should be used to cover these costs, as they are for other TVA economic development programs. Many of the counties around TVA tributary reservoirs are among the poorest counties in the Tennessee Valley region and, thus are appropriate candidates for such assistance.

Using power funds to pay for lake level improvements also would raise equity issues. Many people who commented on the Draft EIS, for example, expressed the view that it would be unfair to require ratepayers, Valley-wide, to pay for water quality and recreation improvements on tributary lakes.

Beneficiary Payment Options

The principal beneficiaries of reservoir system improvements would be Valley residents in tributary areas (east Tennessee, southwest North Carolina, and north Georgia). Several options for allocating the costs of the improvements--primarily the cost of extending lake levels--directly to these beneficiaries were considered. However, none were considered likely to be successful, either alone or in combination. Sufficient funds would not be generated, administrative burdens would be too great, or others whose assistance would be necessary are unlikely to participate on a sustained basis.

Specific options for charging the direct beneficiaries of the proposed lake level improvements are discussed in detail below.

Voluntary Surcharge on Electricity Bills. Electric consumers in tributary lake areas could be asked to contribute a portion of the cost of reservoir system improvements through payments on their monthly electric bills. Because the contribution would be voluntary, there are no legal impediments to this option. However, TVA distributors would have to agree to collect such contributions.

There are roughly 850,000 residential customers in the eastern half of the Tennessee Valley who live close enough to tributary lakes to easily enjoy the benefits from higher summer levels. (This is about 30 percent of the 2.9 million residential customers served by TVA distributors.) If 10 percent of these power consumers paid a voluntary surcharge of $1.00, about $85,000 per month would be raised to defray the costs of the alternatives. This would amount to about $1 million a year.

It would be necessary to survey potential contributors to estimate the actual revenue that could be generated by this means. The only information currently available is an opinion survey of public meeting registrants for the Draft EIS. This survey showed that about half of the respondents from tributary lake areas would be willing to contribute voluntarily to pay for lake levels on their electric bills. Only 60 percent of these indicated the amount they would be willing to contribute; of these, the average contribution was $4 per month.

Because about half of the public meeting registrants live on a lake or river or own shoreline property, they are more likely than other groups to contribute to the cost of lake level improvements. Thus, public meeting survey results probably overestimate the contribution rate that would actually occur. Less than one percent of Knoxville Utilities Board customers, for example, contribute through their monthly electric bills to a fund set up to provide assistance to low income electricity users. Moreover, there is no assurance that initial contribution rates would be sustained.

In addition, TVA would have to seek support for the surcharge from the nine cooperative distributors and 26 municipal distributors of TVA power who serve the targeted customers. The surcharge would have to be explained to affected power consumers by mail or by other means of mass communication and TVA probably would have to reimburse participating distributors for collection costs.

Boating and Fishing Licenses. Because the boating and fishing public would be a principal beneficiary of the proposed reservoir system improvements, the fees for boating and fishing licenses could be raised to recover the costs of the preferred alternatives.

As shown in table 33, in 1988, about 36,000 boating licenses and about 167,000 fishing licenses were sold by the states of Tennessee, Georgia, and North Carolina in the counties surrounding tributary reservoirs. In 1989, boating licenses cost between $4.00 and $16.00, except in Georgia where they were significantly higher. Fishing licenses cost between $3.00 and $25.00. In 1990, the cost of a basic hunting and fishing license in Tennessee increased from $10.00 to $17.50.

Raising the fees for boating and fishing licenses would ensure that the direct beneficiaries pay at least part of the costs of reservoir system improvements. However, there are several problems associated with this funding option. The state agencies or commissions which set boating and fishing license fee schedules would have to agree with the fee increases. Obtaining such agreement probably would be difficult because of the size of the increase that would be necessary. To recover the full cost of holding lake levels higher through August 1, for example, license fees would have to increase by $30 to $35 on the average, plus collection costs.

It also is unlikely that increases of this magnitude would be accepted by the boating and fishing public. Smaller increases would be more acceptable, but would raise a limited amount of money. A fifty-cent increase per license, for example, would generate only about $100,000 annually to offset the costs of the alternatives.

Table 33
Boating and Fishing Licenses
In Tributary Reservoir Counties (by State)

	Boating Licenses		Fishing Licenses	
	Est. No.	Range of Cost	Est. No.	Range of Cost
Georgia	2,000	$10-100	12,000	$3-21
North Carolina	2,000	$ 6	5,000	$3-21
Tennessee	32,000	$ 4-16	150,000	$3-25
Total	36,000		167,000	

Notes:
1. 1988 estimate of number of boating and fishing licenses; 1989 range of costs.
2. Cost of boating licenses varies depending on size of boat, except in North Carolina where one fee is charged for all classes.
3. Cost of fishing licenses varies for resident and non-resident, daily and annual; cost of trout stamps are excluded.

TVA Lake Recreation User Fees. Another option for recovering the costs of lake level improvements from direct beneficiaries is for TVA to collect a recreation user fee at formal access points on affected tributary reservoirs--at boat ramps, campgrounds, boat docks, and marinas, for example.

This, however, would be administratively burdensome. The cost of establishing an adequate collection and enforcement system for the ten tributary lakes is estimated to range from $0.5 to $1 million annually. These costs would have to be added to the costs of the improvements themselves. The amount of the resulting fee would have to be relatively high compared to similar types of fees collected by the states, such as boating and fishing licenses discussed previously. Public acceptance of such a high additional fee is unlikely.

Marina and Boat Dock License Fees. TVA also could collect annual fees from marinas and boat docks on tributary reservoirs, as do some neighboring utilities. TVA already charges an annual fee for marinas and commercial boat docks that are situated on TVA land or cross TVA land to access the water. The average fee is about $1,000, ranging from $400 to $2,000. About 20 to 30 percent of the marinas and boat docks on tributary reservoirs are affected by this policy. Additional revenue could be raised to help offset the cost of lake level improvements by raising these fees and charging all marinas and boat docks an annual license fee. However, because there are only about 100 such facilities on the affected tributary reservoirs, the amount of revenue that could be raised either would be limited, or the fees would be set at such high levels that marina and dock operators likely would object. In addition, some of the marina owners' deeds convey landrights over the TVA shoreland for commercial facility development and a license fee in such cases would constitute double-charging.

Sales and Property Taxes. State and local governments should see an increase in sales and property tax revenue as a result of increased tourism and residential and commercial development due to improved reservoir releases and lake levels. A portion of this increased revenue could be allocated to TVA to cover the cost of the improvements.

Recovering the costs of the alternatives under this option would be a complex undertaking. State legislation would be needed to allocate sales tax revenues to TVA. TVA would have to negotiate allocation of property tax revenues for cost recovery with 21 individual counties (13 in Tennessee, 4 in North Carolina, 3 in Georgia, and 1 in Virginia) and 3 municipalities (2 in Tennessee and 1 in Georgia). State and local governments would have to rely on increased sales and property tax revenue, revenue from other sources such as gas or business taxes, or cut services if they agreed to compensate TVA for lake level improvements. This would be difficult because many of the counties surrounding TVA tributary reservoirs are depressed economically, as noted in Chapter 3.

Refund of Tax-equivalent Payments. State and local governments which would benefit directly from the alternatives could refund some or all of the annual payments they receive from TVA as an equivalent to taxes, as required under Section 13 of the TVA Act. The amount of the payments is equal to five percent of TVA's gross power revenues, less direct sales to federal agencies. The greatest portion of these payments is made to the states, who in turn distribute all or part of it to local governments. In fiscal year 1988, the local governments in the eastern half of the Tennessee Valley surrounding TVA tributary reservoirs received about $12 million of these payments.

Because this option involves only four states--Georgia, North Carolina, Tennessee, and Virginia, in the case of lake level alternatives--it would be relatively easy to administer. However, legislation would have to be passed in each state authorizing the refund of the payments. Local governments would have to rely on revenues from other sources, or cut services if the growth in other revenue sources was less than the payments forfeited from TVA. Even if TVA's tax-equivalent payment to North Carolina was refunded in full, it would not be sufficient to cover the cost of improvements on North Carolina lakes.

Combination of Beneficiary Payment Options. Table 34 summarizes the principal beneficiary payment options identified by the public or TVA staff. The total potential revenue if all options were used is $0.5 to $2.5 million. There would be considerable overlap among the targeted benficiaries and the paying entities, which likely would result in reduced overall revenue. Administrative arrangements for all these options would be complex, involving three state governments, four state wildlife management agencies, 24 local governments, 35 distributors of TVA power, and a new TVA fee collection system.

Only two options--a voluntary surcharge on electricity bills and a refund of tax-equivalent payments--have potential for revenues of $1 million or more. The voluntary surcharge would require the cooperation of 35 distributors of TVA power and significant participation by power customers in the tributary areas to achieve high revenue estimates, which is unlikely. The highest potential refund of tax-equivalent payments would be from the state of Tennessee. However, only about half of the $2 million annual cost of the lake level improvements could be requested because Tennessee lakes account for about half of the total cost. Moreover, it is unlikely that Tennessee state government would voluntarily pay for lake level improvements if other states did not pay their share.

Table 34
Combination of Beneficiary Payment Options

Option	Targeted Beneficiary	Paying Entity[1]	Collecting Entity[2]	Potential Net Revenue[3] ($m)
Voluntary surcharge on electric bills	E. Valley lake users	850,000 power customers	35 power distributors	0.1-1
Boating and fishing licenses	Boating and fishing users	200,000 boaters and fishers	4 state wildlife agencies	0.1
TVA lake user fee	Lake users	Lake users	TVA	0.1
Marina and boat dock licenses	Boat dock and marina users	100 marina and boat dock owners	TVA	0.1
Sales and property taxes	E. Valley lake users	E. Valley taxpayers	24 local governments	0.1
Refund of TVA tax equivalent payments	Lake users on Tennessee, Georgia, and Virginia lakes[4]	States of Tennessee, Georgia, and Virginia	States of Tennessee, Georgia, and Virginia	0 - 1
Total				0.5-2.5

Notes:
1. Maximum potential contributors are estimated, where possible.
2. Assumes collecting entity would agree to collect and disperse funds to TVA, less expenses.
3. Order of magnitude estimate.
4. Not viable for tax-equivalent payments to North Carolina.

SECTION FOUR: SUPPORTING INFORMATION

Glossary

Acid deposition: Transfer of acid materials from the air to the earth's surface (land and water). This is caused by rain or snow (wet deposition) and by particles settling and sticking to vegetation and other surfaces touched by air (dry deposition). Acid materials are both natural and manmade. Burning coal and gasoline causes a significant part of the manmade portion.

Acidification: The process of acidifying water. This can be caused by a number of processes: (1) natural acid in the soil which affects the water flowing through it; (2) the natural decomposition of organic matter; and (3) acid deposition of manmade pollutants (see above).

Aeration (or reaeration): The mixing of air and water, usually by bubbling air through water or by contact of water to air.

Ambient air pollutant concentrations: Amounts of air pollutants present in given amounts of air. It is usually expressed as the weight of the air pollutant in a cubic meter of air (such as in millionths of a gram per cubic meter) or as a ratio of the volume of a pollutant to the volume of air (e.g., parts per million; the number of air pollutant molecules in a million molecules of air).

Aquifers: A porous, water-bearing geologic formation from which water can be pumped via a well. Generally restricted to formations capable of yielding an appreciable supply of water.

Autoventing: The process of allowing air to be automatically sucked into a hydropower turbine to aerate the water being released.

Backwater: Locations along a river where the water level depends on the level at a downstream dam rather than strictly on rate of flow in the stream channel.

Bank slumping: When a portion of the streambank or shoreline suddenly collapses or slides into the stream channel.

Bank stabilization: The physical strengthening of a streambank or shoreline to resist erosion. Typical stabilization techniques include placing of riprap, timbers, tires, or vegetation along the eroding area.

Benthic: Refers to the bottom of lakes and streams and the organisms that live there.

Bioaerosols: Very small solid or liquid particles of biological origin. These include insect parts, particles from animals, bacteria, viruses, molds, fungi, pollen, and other particles from plants.

Biomass: Total weight of plants and animals per unit area (e.g., pounds per acre).

Biweekly minimum flows: An average water flow rate in a river or reservoir over a two-week period, usually expressed as cubic feet per second, that is used as a lower limit on the flow past a specified location such as a hydropower dam. In reservoir operations, short term flow rates (instantaneous or daily average) may vary widely during the two-week period, from very low to very high, as long as the two-week average flow is at or above the biweekly minimum.

Combustion by-products: Gases, liquids, or solids from controlled or uncontrolled burning. Examples include tobacco smoke, carbon dioxide, carbon monoxide, nitrogen dioxide, and water vapor.

Cubic foot: A measure of volume equivalent to about 7.5 gallons.

Deforestation: The clearing or removal of forest or trees.

Deratings: A reduction in the net demonstrated capability of generating equipment caused by turbine, boiler, or condenser deposits; poor quality of fuel; restricted fan, pump, or pulverizer output; etc.

Dewatering areas: Low lying areas isolated from a main stream river channel by a series of dikes which allows those areas to be pumped out or "dewatered" during the spring or summer. These lands can then be used for agricultural or wildlife management purposes; mosquito production is also controlled and timber resources are protected.

Dissolved oxygen (DO): The oxygen that is physically dissolved in water, usually expressed in milligrams per liter. DO is essential to the health of fish and other aquatic life.

Draft tube: Water passage from the hydroturbine to the outlet on the downstream face of the dam (see figure 6).

Drawdown: The lowering of a reservoir water surface, usually measured in feet or in units of storage volume.

Easements: In this document, landrights granted by TVA to state or local governments, private corporations, or individuals usually for a significant use or uses, including recreation, industries, wildlife management, and other resource management or economic development purposes.

Ecosystem: A community of organisms in a region and their surrounding physical resources and conditions.

Effluents: Contaminated water, treated or untreated, discharged through a pipe from a wastewater source. Generally applies to municipal and industrial wastewaters, but can include wastewaters from mining operations, yard drainage from industrial operations, landfills, etc.

Erosion: Natural processes by which soil and/or rocks are moved from one location to another. Typical examples include streambank or shoreline erosion in which soil particles are washed away by the forces of water.

Eutrophic: A water body containing relatively high levels of aquatic plant life, such as high concentrations of algae or high densities of aquatic plants. In the Tennessee Valley, eutrophic conditions are typically desired by most open water fishing enthusiasts, while other recreationists typically desire lower levels of aquatic plants.

Flyway: A large geographic corridor in North America, oriented from north to south, used by migratory birds during seasonal migration flights.

Foraging habitat: An area where an animal or select group of animals search for and obtain food.

Flowage easements: Landrights acquired by TVA over privately owned land which allows such lands to be flooded.

Fossil fuels: Any organic fuel, such as coal, oil, and natural gas.

Hydrology: A branch of science dealing with the waters of the earth, particularly with the occurrence, distribution, and movement of water on and below the earth's surface.

Hydroturbine: A wheel with attached blades (e.g., a propeller) mounted to a shaft by which mechanical energy is produced by the force of water directed against the blades.

Incremental cost: The extra cost of generating or transmitting electricity above the current amount of generation.

Instantaneous minimum flow requirements: A lower limit on the rate of water flow, usually expressed as cubic feet per second, at any given moment past a specified location, such as a hydropower dam or river gaging station. An instantaneous minimum flow is often considered where there is concern about low water levels between periods of hydrogeneration from an upstream dam.

Invertebrates: Animals without backbones (e.g., insects, worms, mussels).

Kilowatthours: The basic unit of electric energy equal to one kilowatt of power supplied to or taken from an electric circuit steadily for one hour.

Large river habitat: The environment provided by rivers at least as large, in the Tennessee Valley, as the Clinch, Holston, or French Broad. Large river habitat has greater river depth and width, including more benthic habitat important for mussels, and can support a more diverse and abundant aquatic community. A larger river can accommodate more fish species (e.g., paddlefish, blue sucker, small-mouth bass, and buffalo) and greater numbers of fish, with abundant non-game species (e.g., minnows and darters) providing more forage for large fish species.

Levee: An embankment, such as a dike, constructed alongside a river to prevent flooding of nearby land during periods of high flow.

Macrophyte: Aquatic plants large enough to be seen by the naked eye.

Marginal strip: The narrow strip of land owned by TVA between the water's edge and the adjoining private property on which the property owner may construct private water use facilities upon approval of plans by TVA.

Mean: A statistical term equivalent to the average.

Modeling: Use of computers to predict the effects of altered reservoir operations, inflow characteristics, channel characteristics, meteorology or other factors influencing water as it passes through the TVA river and reservoir system. Models usually consist of mathematical representations of numerous natural processes (such as heating/cooling, reaeration, biodegradation, mixing) which are integrated into a computer code. Once calibrated to actual field data, models are used to explore effects of management alternatives on the dynamics and water quality of rivers and reservoirs.

Nonpoint source pollution: Contaminants coming from various types of dispersed sources. It usually refers to runoff from land uses, such as agriculture, mining, construction, and urban areas.

Overbank: The low lying area immediately next to a defined stream channel which is occasionally or continuously submerged or subject to flooding.

Penstock: Water passage from the upstream face of a dam to the hydroturbine (see figure 6).

Photosynthesis: Production of food (carbohydrates) by green plants from carbon dioxide and water.

Point source pollution: See effluents.

Potable water: Water that does not contain objectionable pollution, contamination, minerals, or infective agents, and is considered safe to drink.

Power plant efficiency: Ratio of the electrical output of a power plant to the amount of energy in the fuel.

Pulsing: See turbine pulsing.

Radon: Natural, radioactive gas formed from the decay of soil radium. Radon decay provides a small, but sometimes significant, amount of radiation in the human environment.

Reregulation weir: See weir.

Reserve margin: The amount of generating capacity in excess of peak power demands.

Riffle: A short section of river characterized by shallow, fast-moving, turbulent water, such as shoals or rapids.

Riparian: Pertaining to the bank of a river, lake, or other body of water.

Riverine: Relating to a river, as in a riverine environment. Often contrasted to a lacustrine or lake-like environment.

Sedimentation: The natural processes by which soil and other materials are eroded, transported, deposited, and compacted by water.

Shorebirds: A group of highly migratory birds, typically with long legs, pointed wings, and gray-brown bodies, that feed along the shorelines of lakes, reservoirs, streams, and oceans.

Sluiceways: Passages through a dam which are used to discharge water without producing power (see figure 6). At most TVA projects, the sluice intakes are located deep in the reservoirs near the bottom of the dam.

Spillways: Structures designed to allow relatively high flows of water over the top of the dam or through a separate structure (see figure 6). Spillways may be gated or uncontrolled.

Spinning reserve: The status of a hydroelectric or thermal generating unit in which it is immediately available for use.

Stage: The height of the water surface elevation above some arbitrary reference elevation.

Subimpoundments: Portions of a larger reservoir area separated by additional dikes, levees, or dams, which allow the water level in the smaller area to be regulated independently of the larger area.

Substrate: The bottom of a river or reservoir in or on which animals and plants live.

Tailings: Solid material which is deposited by a flowing liquid, and accumulates in one area, such as waste materials from a mine.

Tailwater: The portion of a river immediately downstream from a dam.

Temperature stratification: The variation of temperature with depth in a reservoir. The coldest water is typically the densest water and is found on the bottom of the reservoir, whereas the warmest water is found at the surface. Usually, in the Tennessee Valley, reservoirs begin stratifying in the spring and become very stratified in May and June; stratification disappears by winter.

Terrestrial: Living on or consisting of land or soil, as distinguished from water or air.

Thermal plant: A facility to produce electric energy from heat energy released by combustion of a fossil fuel or consumption of a fissionable material.

Thermal shock: Physiological stress produced in an organism by a rapid change in temperature.

Topography: The physical features of a place or region. Commonly refers to land forms and variation in elevations.

Tributary: A river or stream flowing into a larger stream. In context of this report, refers to the streams and rivers which eventually flow into the Tennessee River.

Turbine pulsing: Operating a hydroturbine for a short duration (15 to 60 minutes), often at regular intervals ranging from 2 to 24 hours apart. Pulsing is often done between turbine generating periods to maintain a minimum flow at some downstream location.

Waterbirds: A group of birds, represented by many families, that are dependent on water-based habitats to meet a part of their life requisites of food and shelter.

Water column: A vertical portion of water above the bottom of a stream or reservoir.

Waterfowl: A family of birds, including ducks, geese, and swans, that have webbed feet, long necks, and narrow pointed wings; are dependent on aquatic habitats; and typically migrate from spring nesting areas in the north to wintering areas in the south.

Weirs: Structures placed in a river to back up or divert water. Generally these structures are less than 10 feet in height and are designed to pass water over the top of their entire length; could be considered as low dams.

Withdrawal zone: The region within a reservoir from which water is removed during release through an outlet at the dam. Withdrawal zones are characterized by their vertical and lateral extent. Hydroturbines, sluices, and spillways each have unique withdrawal zones. The withdrawal zone for each outlet is dependent on physical processes that vary with time, including flow rate through the outlet and density stratification due to temperature differences between surface and deeper layers in the reservoir.

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