This alternative would require consultation with the FWS. No other consultations or permits are required.

If this alternative is implemented before the restart of L-Reactor, the environmental impacts would be as described above (successional recovery of about 730 to 1000 acres of wetlands). If it is implemented after direct discharge occurs, the environmental impacts would be the same as those described in Section 4.4.2.2.1 (i.e., loss of 730 to 1000 acres of wetlands, etc.). Any mitigative effects resulting from this alternative would not begin until the end of the 27-month construction period.

4.4.2.3.3 Cooling towers--partial recirculation

4.4.2.3.3.1 Partial recirculation--discharge to Steel Creek

Cooling towers (2.8°C or 8.4°C approach temperature) that only recirculate a portion of the cooling water could be added to the L-Reactor site. From April through October the towers would cool water on a once-through basis and discharge all the effluent directly to Steel Creek. Based on equilibrium temperature calculations for these months, the discharge to Steel Creek under normal weather conditions would continuously meet the 32.2°C/+2.8°C temperature criteria if a 2.8°C approach cooling tower is used. Equilibrium temperature calculations indicate that, from November through March (Du Pont, 1983d,e), a portion of the cooling water must be recirculated to the 186-Basin. Table 4-50 lists the percent of the cooling-water flow exiting the cooling tower that would be allowed to discharge into Steel Creek. The percent of direct river water flow indicated in Table 4-50 is the blending water that would be mixed with the cooling-tower discharge to meet the State +2.8°C temperature criteria.

Table 4-50. Cooling-water usage for cooling-tower system with partial recirculation (2.8°C approach temperature tower)

Month	Percent of cooling tower flow into creek (tower discharge)	Percent of river water diverted directly to Steel Creek (blending water)
November	34	66
December	12	88
January	22	78
February	46	54
March	74	26

This alternative would require the construction of cooling towers adjacent to the reactor (Figure 4-33) as described for the complete recirculation tower alternative. In addition, a diversion box and piping would be required to direct the cooling water to either Steel Creek or the 186-L reservoir. About 27 months would be required to design and construct this alternative. Construction would take place away from Steel Creek. A shutdown of about 1 month would be

required while all new facilities are completed if L-Reactor is operated before the construction of this alternative.

Capital costs for this alternative are an estimated to $70 million (2.8°C approach), and annual operating costs are an estimated $5.5 million. Present worth of this alternative would be about $140 million and the annualized cost would be about $16.4 million (Du Pont, 1983d). An estimated 150 construction personnel would be required.

Production efficiency is estimated to be about 97.5 percent of that for the direct discharge reference case. The values in Table 4-50 are based on daily average temperatures in Steel Creek. River water withdrawal requirements would be 100 percent of the discharge and evaporation flow rates. The discharge rate for this alternative would be 10.9 cubic meters per second.

Because of the potential need for blending with river water to meet State discharge criteria, cooling water at near-ambient temperatures would be discharged to Steel Creek. Table 4-51 and Figure 4-37 present the seasonal maximum downstream temperatures in Steel Creek. Thus, there would be no appreciable impacts on the temperatures of Steel Creek or Savannah River water from the cooling-tower discharges.

Table 4-51. Temperatures (°C) downstream in Steel Creek with cooling towers with partial recirculation (2.8°C approach)

Location	Summer[a]	Summer[b]	Spring[b]	Winter[b]
Discharge temperature[c]	28	27	23	11
Road A	29	28	23	11
Swamp at delta	30	28	23	10
Mid-swamp	29	27	21	9
Mouth of creek at river	29	27	21	10

[a]Based on worst 5-day meteorological conditions (July 11-15, 1980) and estimated operating power of the reactor.

[b]Based on 30-year average values for meteorological conditions (1953-1982) and the actual power of an operating reactor. Summer average temperatures have been included to show the discharge and Steel Creek temperatures that could be expected if significant temperature excursions above and below average did not occur.

[c]Temperature of water entering Steel Creek.

The 2.8°C approach temperature tower would meet State discharge limits of 32.2°C at all times, as indicated in Table 4-51.

A cooling tower designed for an 8.4°C approach temperature would result in summer cooling-water discharge temperatures about 5°C higher than the 2.8°C approach temperature tower. Adding more than 5°C to Table 4-51 would result in noncompliance with State discharge limits.

The 8.4°C approach temperature tower would also increase the blending water required, and would result in discharge rates that could significantly exceed 10.3 cubic meters per second if blending were to be applied during the summer months. The use of an 8.4°C approach temperature tower would be much less desirable, for these reasons, than a 2.8°C tower in this alternative. Because an 8.4°C approach tower in a partial recirculation system would not comply with State discharge requirements, even with flow rates greater than 11 cubic meters per second, it has been dropped from further consideration.

Partial-recirculation cooling towers would be in normal compliance with discharge criteria with infrequent excursions. These excursions are predicted to occur at night during January, February, and March, for 1 to 4 hours. Only the Steel Creek temperature rise criterion would be exceeded at these times (Du Pont, 1983d).

Because the duration and rate of discharge (10.9 cubic meters per second) for this alternative (2.8°C approach) are nearly identical to that for cooling towers with direct discharge (Section 4.4.2.3.1.1), the environmental impacts would be the same. Although near-ambient temperatures would be achieved from the outfall to the Savannah River, the effluent flow would have adverse effects on the environment. Emergent macrophytes and other wetland flora would be uprooted by the increased flow rate, and the delta would grow at a rate of about 3 surface acres per year. Summer and spring temperatures of Steel Creek above the delta would be about 1°C above ambient, and 3°C above ambient in winter. Water temperatures at the mouth of Steel Creek would be about ambient in summer and spring, and 2°C above ambient in winter. Thus, thermal effects to aquatic biota would not be significant.

Except for the mitigating effects associated with lower discharge temperatures, the environmental impacts caused by this alternative (2.8°C approach) would be similar to those for direct discharge; they are summarized as follows:

- The high flow rate would impact between 420 and 580 acres of wetlands within the Steel Creek corridor. Because the effluent would not have elevated temperatures, the high flow rate would impact between 70 to 80 percent of that area of the delta predicted for direct discharge. Thus, between 215 and 335 acres would be eliminated (or a total of 635 to 915 acres of wetlands). The wetlands that would be impacted by this alternative are classified as Resource Category 2 by the U.S. Fish and Wildlife Service. This resource category and designation criteria include "high value for evaluation species and scarce or becoming scarce" (USDOI, 1981). The mitigation planning goal specifies that there be "no net loss of inkind habitat value." About 30 acres of uplands would be impacted for the construction of the cooling towers.

- Foraging sites for the endangered wood stork would be eliminated due to increased water levels.

- The impingement of 16 fish per day (5840 fish per year), and the annual entrainment of 7.7×10^6 fish eggs and 11.9×10^6 fish larvae would occur.

- About 3.4 curies would be transported the first year using a 2.8°C approach; an 8.4°C approach would release 3.5 curies. Liquid releases of tritium to the Savannah River would be about 8800 curies per year.

- Atmospheric releases would result in (1) a maximum of 5 hours per year of fogging (i.e., visibility reduced to less than 1000 meters) within about 1.0 kilometer of the towers, and (2) a maximum of 55 hours per year of ice accumulation on horizontal surfaces. An estimated 0.37 kilogram per acre per month of salts would be emitted within about 1.0 kilometer of the towers.

- Potential impacts to five archeological sites eligible for the National Register. A mitigation plan would be developed and implemented prior to restart similar to that described under direct discharge.

- No impacts to substrate, water quality, or water levels due to dredging or filling.

- Increased sedimentation and erosion due to effluent discharge; delta growth is anticipated to be 3 surface acres per year.

This alternative would require the following permits or processes: (1) an NPDES permit, (2) consultations with the FWS, and (3) the preparation of a biological assessment for endangered species.

If this alternative is implemented before the restart of L-Reactor, the environmental impacts would be as described above (i.e., loss of 635 to 915 acres of wetlands). If it is implemented after direct discharge occurs, the environmental impacts would be the same as those described in Section 4.4.2.2.1 (i.e., loss of 730 to 1000 acres of wetlands, etc.). Any mitigative effects resulting from this alternative would not begin until the end of the 27-month construction period.

4.4.2.3.3.2 Partial recirculation--with refrigeration

This alternative is the same as the partial recirculation case described in Section 4.4.2.3.3.1 with the addition of a refrigeration unit that would be used primarily at night during the winter, to meet State discharge criteria. The refrigeration system would operate about 2 to 5 hours per night from January through March. During those hours, about 1 cubic meter per second would be diverted through the refrigeration unit to give a mixed Steel Creek temperature that complies with State discharge temperature requirements.

The estimated construction time would be 27 months, with a downtime of about 1 month for system connection, assuming L-Reactor would be operating before this alternative is implemented.

Capital costs would be about $85 million, and maintenance and operating costs would be about $5.7 million. Present worth would be $157 million and annualized cost would be $18.4 million (Du Pont, 1983d). An estimated 180 construction personnel would be required.

The production efficiency would be about 97.5 percent. Partial recirculation alternatives would discharge 10.9 cubic meters per second into Steel Creek, and total recirculation alternatives discharge only about 0.6 cubic meter per second.

Average ambient temperatures at Road A in Steel Creek are 29°C in summer, 22°C in spring, and 8°C in winter (Du Pont, 1983d). Table 4-52 lists downstream temperatures by season.

Table 4-52. Temperatures (°C) downstream in Steel Creek with partial recirculation with refrigeration (2.8°C approach)

Location	Summer[a]	Summer[b]	Spring[b]	Winter[b]
Discharge temperature[c]	28	27	23	11
Road A	29	28	23	11
Swamp at delta	30	28	23	10
Mid-swamp	29	27	21	9
Mouth of creek at river	29	27	21	10

[a]Based on worst 5-day meteorological conditions (July 11-15, 1980) and estimated operating power of the reactor.

[b]Based on 30-year average values for meteorological conditions (1953-1982) and the actual power of an operating reactor. Summer average temperatures have been included to show the discharge and Steel Creek temperatures that could be expected if significant temperature excursions above and below average did not occur.

[c]Temperature of water entering Steel Creek.

Using a 2.8°C approach tower and a refrigeration unit, near-ambient creek temperature would be achieved continuously. Partial recirculation cooling towers (2.8°C approach) with refrigeration would, therefore, meet State discharge requirements, continuously.

Cooling towers with partial recirculation and refrigeration (2.8°C approach) would have thermal consequences that are similar to those from cooling towers with total recirculation and refrigeration (2.8°C approach). Thus, the environmental effects of this alternative would be essentially the same as those of the partial recirculation alternative without refrigeration. In general, environmental effects are summarized as follows:

- The high flow rate would impact between 420 and 580 acres of wetlands within the Steel Creek corridor. Because the effluent would not have markedly elevated temperatures, high flow rate would impact between 70 to 80 percent of that area predicted for direct discharge. Thus, between 215 and 335 acres would be impacted (or a total of 635 to 915 acres of wetlands). The wetlands that would be impacted by this alternative are classified as Resource Category 2 by the U.S. Fish and Wildlife Service. This resource category and designation criteria include "high value for evaluation species and scarce or becoming scarce." The

mitigation planning goal specifies that there be "no net loss of inkind habitat value" (USDOI, 1981). About 30 acres of uplands would be impacted for the construction of the cooling towers.

- Foraging sites for the endangered wood stork would be eliminated due to increased water levels.

- The impingement of 16 fish per day (5840 fish per year), would occur, as would the annual entrainment of 7.7×10^6 fish eggs and 11.9×10^6 fish larvae.

- The transport of 3.4 curies of radiocesium would occur the first year using a 2.8°C approach. Liquid releases of tritium to the Savannah River would be about 8800 curies per year.

- Nonradioactive atmospheric releases would result in (1) a maximum of 5 hours per year of fogging (i.e., visibility reduced to less than 1000 meters) within about 1.0 kilometer of the towers, and (2) a maximum of 55 hours per year of ice accumulation on horizontal surfaces. An estimated 0.37 kilogram per acre per month of salts would be emitted within 1.0 kilometer of the towers.

- Potential impacts to five archeological sites eligible for the National Register. A mitigation plan would be developed and implemented prior to restart similar to that described for direct discharge.

- No impacts to substrate, water quality, or water levels due to dredging or filling.

Impacts to wetlands from this alternative would be the same as those for partial recirculation without refrigeration. High flow would affect between 420 and 580 acres in the Steel Creek corridor, and between 215 and 335 acres of wetlands in the delta and swamp.

This alternative would require the following permits or processes: (1) an NPDES permit, (2) consultations with the FWS, and (3) the preparation of a biological assessment for endangered species.

If this alternative is implemented before direct discharge occurs, the environmental impacts would be as described above (i.e., loss of 635 to 915 acres of wetlands). If it is implemented after direct discharge occurs, the environmental impacts would be the same as those described in Section 4.4.2.2.1 (i.e., loss of 730 to 1000 acres of wetlands, etc.). Any mitigative effects resulting from this alternative would not begin until the end of the 27-month construction period.

4.4.2.4 Other recirculation alternatives

Four alternative cooling systems were evaluated that would recirculate cooling water through impoundments located on the SRP. Impoundments that would require new design and construction include L-Pond, the High-Level Pond, and

Kal Pond. Par Pond, an existing impoundment that is currently used to cool P-Reactor, could also be used to cool L-Reactor.

DOE would perform safety analyses for the design of the cooling-lake embankment to ensure stability during construction, closure, filling, drawdown, and under all conditions of lake operation, including appropriate earthquake loading. The design will also assure that the embankment is safe against overtopping during the inflow of the design flood and during wave action. These analyses will be performed to ensure public safety, because a failure of the cooling-lake dam could have adverse impacts on portions of the Seaboard Coast Line Railroad and South Carolina Highway 125 (SRP Road A) where they cross Steel Creek or other onsite streams below a cooling lake.

Impounded water for a cooling lake would cause a local ground-water mound in the water-table aquifer. This effect of the lake would dissipate with depth and is expected to have only a small effect on water levels in the McBean Formation. The green clay is an important confining unit separating the McBean from the underlying Congaree Formation. It would prevent the increased head associated with a cooling lake from impacting the head differential between the Tuscaloosa and Congaree Formations (see Figure 3-9). It is also an important barrier to the migration of contaminants from near the surface to lower hydrostratigraphic units. In the Separations Areas, the green clay (about 2 meters thick) supports a head difference of about 24 meters between the McBean and Congaree Formations. Based on water samples obtained for tritium analysis from the Congaree near the H-Area seepage basin, the green clay has effectively protected the Congaree ground water from contamination seeping into the ground (Marine, 1965). In the L-Area, the green clay is about 7 meters thick. At the Par Pond pumphouse along the strike of the McBean and Congaree Formations, the green clay also supports a large head difference; the water pumped from the Congaree Formation shows no evidence of tritium contamination even though tritium concentrations in that lake were measured at 27,000 picocuries per liter. Water pumped from the Congaree by the pumphouse well exhibited tritium concentrations of 170 picocuries per liter or less in comparison to concentrations of 260 ± 60 picocuries per liter in offsite well water (Ashley and Zeigler, 1981).

4.4.2.4.1 L-Pond

The damming of Steel Creek to form a lake, L-Pond, to accept heated effluent from L-Reactor has been investigated. The discharge from L-Reactor would enter L-Pond directly without any precooling. Cooled water from the lake would be pumped back to the L-Reactor reservoir for recirculation through the reactor.

Under this alternative, an earthen embankment would be constructed across Steel Creek approximately 750 meters above the Seaboard Coast Line Railroad bridge (Figure 4-38). This embankment would be approximately 32 meters high and about 1500 meters long, impounding just over 1300 acres, with a normal pool elevation of 61 meters above mean sea level. The total amount of earth fill required to construct the embankment would be 840,000 cubic meters. Several earthen berms would be required to prevent high water from overflowing natural saddles near the east and north ends of the lake.

The creation of L-Pond would require the relocation of two 115-kilovolt electric transmission and buried supervisor control and relay cable lines that cross Steel Creek near Road A-14. Approximately 1400 meters of South Carolina

Electric and Gas Company 115-kilovolt transmission line would be replaced by steel towers and new conductor cable to enable the line to span the widened waterway. Several SRP roads inundated by the lake would be abandoned or raised.

A new pumping station, similar to but smaller than the existing Par Pond station, would be constructed on the northwest shore of the lake near Road A-14. The power for this station would be run from the existing 504-3G substation approximately 1200 meters away. A new pipeline generally paralleling the northwest shore of the pond would carry cooled water back to the L-Reactor reservoir. Access roads for construction activities would be routed to minimize environmental impacts. About 40 months would be required to design and construct this alternative (Du Pont, 1983d).

This alternative is similar to the 500-acre lake, except the dam and lake are larger. The construction of the recirculation portion would not affect reactor operation. A shutdown of about 1 month would be required to divert the stream through the discharge structure.

The estimated capital costs for L-Pond would be $73 million, with annual operating expenses of $2.9 million. The present worth would be $135 million and the annualized cost would be $15.9 million (Du Pont, 1983d). An estimated 630 construction personnel would be required.

The relative production efficiency of this alternative is expected to be 96 percent of that for the direct discharge option. The water discharge rate to Steel Creek would be about 0.5 cubic meter per second and would consist of the overflow from L-Pond. Makeup water temperatures from the Savannah River to L-Pond would have minor effects on L-Pond temperature and reactor operation.

Under extreme summer meteorological conditions, the overflow to Steel Creek would have an exit temperature of about 33°C, which is 2°C above ambient in summer at Road A. Near-ambient temperatures should be reached at the Steel Creek delta in the spring and summer. Thus, this alternative would not increase the water temperatures of the Savannah River.

The thermal behavior of L-Pond is expected to be similar to that of Par Pond. L-Pond should experience thermal stratification from April through October and it should be well mixed from November through March. During periods of thermal stratification, the hypolimnion could become intensely anoxic, with ferrous iron and other metals being dissolved from the sediment (Marshall and LeRoy, 1971). Seasonal cycling of cesium-137, similar to that found in Par Pond (Alberts et al., 1979), is probable in L-Pond.

This alternative would provide normal compliance with the maximum 32.2°C discharge temperature limit rise in Steel Creek except during extreme summer meteorological conditions.

Near-ambient temperatures would be reached at the Steel Creek delta, allowing continuing successional recovery of the swamp with associated utilization by aquatic and terrestrial species (fish, waterfowl, wood stork, and the American alligator). Delta growth under this alternative is expected to be near zero.

The L-Pond alternative would inundate approximately 1060 acres of upland pine. This lake would support minimal aquatic life because of a continually

high water temperature. Isolated cool-water refuges might be utilized minimally by aquatic (fish) and semiaquatic (herpetofauna, wading birds, beaver) biota.

This alternative would inundate approximately 7.6 kilometers of Steel Creek from just north of Road B to the dam (Figure 4-38). Thus, about 240 acres of wetlands including active habitat of the American alligator would be inundated. The wetlands that would be impacted by this alternative are classified as Resource Category 2 by the U.S. Fish and Wildlife Service. This resource category and designation criteria include "high value for evaluation species and scarce or becoming scarce" (USDOI, 1981). The mitigation planning goal specifies that there be "no net loss of inkind habitat value." If releases from L-Pond into Steel Creek are maintained near the average natural flow (i.e., 0.6 cubic meter per second), foraging habitat of the endangered wood stork would not be affected. Additionally, this option would have no impact on the shortnose sturgeon.

The makeup water required for L-Pond would represent a 9-percent increase (1.8 cubic meters per second) over present SRP intake withdrawal rates from the Savannah River. This increase would result in impingement and entrainment losses from the river of about 956 additional fish per year and 1.3×10^6 fish eggs and 1.9×10^6 fish larvae per year, respectively.

The transport of radiocesium off the site is expected to amount to about 0.8 curie per year, about half the amount presently transported (Hayes, 1981). Approximately 24 curies of the cesium-137 currently in the Steel Creek channel and floodplain would lie beneath L-Pond. This alternative would release 2170 curies per year of tritium from L-Reactor to the Savannah River.

Nonradioactive atmospheric releases would result in a maximum of 130 hours per year of reduced visibility (less than 0.8 kilometer) on the leeward side of the impoundment, and a maximum of 115 hours per year of ice accumulation on horizontal surfaces. No deposition of salts due to drift is expected.

The area subject to impact by this alternative contains 10 archeological sites. Two to four sites could be inundated. A mitigation plan would be developed and implemented prior to restart similar to that described under direct discharge.

The inundation of 1300 acres would modify the bottom contours of the substrate and create vastly different patterns in water circulation, depth (32 meters at the dam), and temperature. The diversity and abundance of benthic organisms would also be markedly changed. Excavation of the creekbed for dam construction would necessitate the disposal of approximately 3000 cubic meters of possibly contaminated spoil. The overflow from L-Pond, which would be discharged into Steel Creek, would have a minimal impact on the substrate of the creek or its delta.

Spoil from the surface portion of the embankment foundation in the Steel Creek floodplain, estimated to contain a total of 0.2 curie of cesium-137 and 0.02 curie of cobalt-60, would be separated, contained, replaced outside the jurisdictional wetlands upstream of the embankment, and covered with subsurface spoil to prevent erosion during the construction period. This relocation would have no effect on net cesium transport estimates. All uncontaminated material would be removed and used for backfill in the borrow areas. Thus, any impacts

on water quality and turbidity in the L-Pond would be temporary until suspended particulates settle and bottom sediments stabilize. Seasonal cycling of any remaining cesium-137 is probable in L-Pond (Alberts et al., 1979). The water quality of L-Pond should be very similar to that of Par Pond. An ion-concentration ratio (lake-to-river) of 1.0 to 2.5 is expected for L-Pond. Necessary precautions would be taken during embankment construction to contain suspended particulates and sediment from moving into the Steel Creek corridor. Embankment construction and L-Pond overflow is expected to have a minimal impact in water quality and turbidity in Steel Creek and the swamp.

L-Pond construction would vastly alter water levels and circulation patterns over the 1300 acres. Erosion control and removal of the excavated material would minimize the discharge of material that could obstruct or change the direction or velocity of flows both above the embankment and in Steel Creek below the embankment. The small increase in water levels below the embankment should have minimal impact on Steel Creek and the swamp.

This alternative would require the following permits or processes: (1) a U.S. Army COE 404 permit, (2) an SCDHEC 401 certification, (3) an NPDES permit, (4) a 316(a) demonstration, (5) consultations with the FWS, and (6) the preparation of a biological assessment for endangered species.

If this alternative is implemented before the restart of L-Reactor, the environmental impacts would be as described above. If it is implemented after direct discharge occurs, the environmental impacts would be the same as those described in Section 4.4.2.2.1 for once-through direct discharge (i.e., loss of 730 to 1000 acres of wetlands, etc.). The mitigative effects resulting from this alternative are that the Steel Creek ecosystem and swamp below the L-Pond dam would not be impacted. This would not begin until the end of the 40-month construction period.

4.4.2.4.2 Kal Pond

The feasibility of creating Kal Pond, which would serve both K- and L-Reactors, has been studied. Such a lake would not only mitigate thermal impacts associated with a direct discharge to Steel Creek by L-Reactor, it would also mitigate thermal impacts of K-Reactor on Indian Grave Branch and Pen Branch. Heated effluent from both reactors would enter Kal Pond; after natural cooling, it would be pumped back to the reactors for recirculation.

One large 2620-acre lake would be created by constructing embankments across both Steel Creek and Pen Branch (Figure 4-39). The Pen Branch embankment would be approximately 750 meters above Road A and the Steel Creek embankment would be about 300 meters above Road A-14. The location of the embankment on Steel Creek would eliminate any impact on one of the two 115-kilovolt transmission and control cable lines mentioned for L-Pond. It would also allow Road A-14 to remain undisturbed and would reduce the maximum height of the Steel Creek embankment by about 5 meters. The Pen Branch embankment would be approximately 800 meters long and the Steel Creek embankment would extend about 1400 meters. About 900,000 cubic meters of fill would be required to construct the two embankments. The normal water-surface elevation would be about 64 meters. This water level would necessitate raising, rerouting, or abandoning several SRP roads. Access roads for construction activities would be routed to minimize environmental impacts.

A new outlet structure would be constructed at the edge of the new lake north of the abandoned section of Road B. Few modifications would be required at the K-Reactor discharge because the present canal extends above the elevation of the proposed water level.

Some modifications would have to be made to the K-Area-to-L-Area steam line and the river water lines serving K-, L-, and P-Reactors because Kal Pond would flood the areas where they cross Indian Grave Branch and Pen Branch.

Two 115-kilovolt transmission lines and control cables would have to be relocated, one along Steel Creek and another paralleling Indian Grave Branch. In addition, steel towers and new conductor would be needed where another 115-kilovolt transmission line and control cable line cross Pen Branch near Road C, where the Steel Creek lines cross the new lake south of Road B, and where the Indian Grave Branch lines cross the new lake near Road B.

The amount of time required to design and construct this alternative would be between 60 and 66 months (Du Pont, 1983d). This alternative would require about a 1-month downtime for both K- and L-Reactors. However, the shutdown of the two reactors could be scheduled at the same or different times, as desired.

Because of its structural complexity, capital costs for Kal Pond are estimated to be $190 million, the most costly of the alternatives (Du Pont, 1983d). Annual operating costs would be approximately $2 million. The present worth of this alternative would be $299 million and the annualized cost would be $35 million (Du Pont, 1983d). An estimated 870 construction personnel would be required.

The production efficiency of Kal Pond would be about 96 percent (derived from Du Pont, 1983d). Elevated Savannah River temperatures would not directly affect reactor operation. Makeup to Kal Pond would require 3.5 cubic meters per second from the Savannah River; of this total, about 0.5 cubic meter per second would be released to Pen Branch and Steel Creek.

Under extreme summer meteorological conditions, the overflow would have an exit temperature of about 33°C. Under average conditions, the discharge temperature would be about 31°C. Near-ambient temperatures should be reached at the Steel Creek and Pen Branch deltas. Thus, this alternative would have minor effects on the temperature of the Savannah River water. The water discharge rate from Kal Pond to Steel Creek and Pen Branch would be equal to their normal seasonal flow rates.

This alternative would provide normal compliance with the maximum 32.2°C discharge temperature limit.

Kal Pond is expected to show thermal behavior much like that of Par Pond. It should experience thermal stratification from April through October, and should be well mixed from November through March. During periods of thermal stratification, the hypolimnion could become intensely anoxic with ferrous iron and other metals being dissolved from the sediment (Marshall and LeRoy, 1971). The seasonal cycling of cesium-137, which follows the seasonal stratification cycle (Alberts et al., 1979), would be probable.

Because this recirculation alternative would greatly reduce the thermal discharge to Steel Creek, it would result in a significant reduction in impacts to the biota of the creek, its delta, the floodplain, and the Savannah River in comparison to the effects caused by direct discharge. A reduction of thermal impacts to Pen Branch and the Pen Branch delta would also occur.

Approximately 615 acres of riparian wetlands and 2005 acres of upland conifers would be inundated by the Kal impoundment. This would include 7.0 kilometers along Pen Branch, 5.0 kilometers along Steel Creek, and 4.0 kilometers along Indian Grave Branch. The wetlands that would be impacted by this alternative are classified as Resource Category 2 by the U.S. Fish and Wildlife Service. This resource category and designation criteria include "high value for evaluation species and scarce or becoming scarce" (USDOI, 1981). The mitigation planning goal specifies that there be "no net loss of inkind habitat value." This impoundment would flood forested habitats that once contained the endangered red-cockaded woodpecker. This lake would support minimal aquatic life because of continually high water temperatures.

Kal Pond would require a maximum of 3.5 cubic meters per second of water from the Savannah River. Assuming that K-Reactor currently uses 17 cubic meters of water per second, the current impingement is about 5840 fish per year (based on the latest 12 months of data) and the current entrainment is 7.7×10^6 eggs (1982 data) and 11.9×10^6 larvae (1983 data) per year. These values would decrease to 1858 fish per year and 2.5×10^6 eggs and 3.8×10^6 larvae per year, respectively, for the combined operation of K- and L-Reactors.

Radiocesium transport from Steel Creek is expected to be about 0.8 curie per year. Small quantities of radiocesium also would be delivered to the river and swamp from Pen Branch. Approximately 20 curies of cesium-137 that are in the Steel Creek channel and floodplain would lie beneath the lake. In addition, the Savannah River would receive about 870 curies of tritium per year from L-Reactor.

Nonradioactive atmospheric releases would result in (1) a maximum of 25 hours per year reduced visibility (less than 800 meters) on the leeward side of the impoundment, and (2) a maximum of 15 hours per year of ice accumulation on horizontal surfaces. No deposition of salts due to drift is expected.

Twenty-nine archeological sites could be affected by this alternative. Of these, 8 to 10 sites could be flooded. A mitigation plan would be developed and implemented prior to restart similar to that described for direct discharge.

Little or no change is expected in the substrate, erosion, or sedimentation patterns in Steel Creek or Pen Branch because the overflow would not produce large increases to their normal flows and because, below the reactor outfalls, the streams are in approximate equilibrium for flow rates of 11 cubic meters per second.

Spoil from the surface portion of the embankment foundation in the Steel Creek floodplain, estimated to contain a total of 0.2 curie of cesium-137 and 0.02 curie of cobalt-60, would be separated, contained, replaced outside the jurisdictional wetlands upstream of the embankment, and covered with subsurface spoil to prevent erosion during the construction period. This relocation would

have no effect on net cesium transport estimates. All uncontaminated material would be removed and used for backfill in the borrow areas.

The chemical characteristics of the overflow to either stream are expected to be similar to those of Savannah River water and the natural conditions of the receiving streams. No appreciable changes in the characteristics of the blowdown should occur as the result of river water (makeup) passing through Kal Pond, except its concentration of suspended solids would be lower. The water quality of Kal Pond should be similar to that of Par Pond; these lakes would be nearly equal in size (Kal Pond would contain 8.37×10^7 cubic meters and Par Pond contains 6.62×10^7 cubic meters). An ion-concentration (lake-to-river-water) ratio of 1.0 to 3.2 is expected for Kal Pond (Tilly, 1974). The concentration of tritium could reach 91,000 picocuries per liter, about 2.5 times the 7-year Par Pond average.

Kal Pond construction would vastly alter water levels and circulation patterns over 2620 acres, which would affect Steel Creek, Pen Branch, and Indian Grave Branch upstream of the dam. Erosion control and removal of much of the dredged material to the onsite burial ground would minimize the discharge of material that could obstruct or change the direction or velocity of flows both above the embankments and in Steel Creek and Pen Branch below the embankments.

This alternative would require the following permits or processes: (1) a U.S. Army COE 404 permit, (2) an SCDHEC 401 certification, (3) an NPDES permit, (4) a 316(a) demonstration, (5) consultations with the FWS, and (6) the preparation of a biological assessment for endangered species.

If this alternative is implemented before direct discharge occurs, the environmental impacts would be as described above. If it is implemented after direct discharge occurs, the environmental impacts would include those described in Section 4.4.2.2.1 (i.e., loss of 730 to 1000 acres of wetlands, etc.) plus those (i.e., 615 acres of wetlands and 2005 acres of uplands) resulting from the Kal Pond alternative. Any mitigative effects resulting from this alternative would not begin until the end of the 66-month construction period.

4.4.2.4.3 High-Level Pond

Two embankment sites across Pen Branch were studied for the construction of a High-Level Pond; both would provide the same water elevation (83 meters). The first site would have provided a lake area of approximately 1225 acres, which could not match the cooling efficiency of the other cooling lakes studied. Therefore, a second site (Figure 4-40) was studied that would add 560 acres to the first lake. The embankment for the second lake would be about 2750 meters long with a maximum height of 35 meters. Two sections of earthen berm would be constructed across a natural saddle west of this embankment; they would total 460 meters long but not more than 3 meters high. The total amount of material required to construct the embankments would be 1,900,000 cubic meters.

This lake would be upstream from the existing river water lines and, therefore, would have no impact on them or on the steam line from K-Reactor to L-Reactor. However, it would require the abandonment of Road C between Roads 6 and 7; approximately 1200 meters of Road 6 would have to be raised as much as 12 meters. About 6 kilometers of 115-kilovolt transmission line and its buried

supervisor control cable would have to be relocated. Access roads for construction activities would be routed to minimize environmental impacts.

Thermal effluent from L-Reactor would flow through existing pipes to a new reinforced concrete sump, similar to that required by the cooling-tower alternative. The pumps in this sump would pump the hot water through a new pipeline to discharge into the High-Level Pond. The water would flow through the lake to an intake structure near the embankment. A new pipeline would run 1750 meters, from the intake structure, through the embankment, and to the L-Reactor lake. Valves would control the gravity flow to provide the quantity of water required for reactor cooling. Approximately 42 to 48 months would be required to design, construct, and permit this alternative.

L-Reactor shutdown time under this alternative would be the same as that for the cooling towers, because the same pumping system would be constructed. All other construction would take place away from the effluent system.

Estimated capital costs for the High-Level Pond would be about $120 million. Annual operating costs should approach $1.9 million. The present worth of this alternative would be $174 million and the annualized cost would be $20.4 million (Du Pont, 1983a). An estimated 1215 construction personnel would be required.

The High-Level Pond is estimated to have a relative production efficiency of 96 percent. This alternative would allow all of Steel Creek to remain in post-thermal recovery, unaffected by cooling-water effluents from L-Reactor. In addition, thermal discharges to the Savannah River and its associated floodplain swamp would remain at present levels. High-Level Pond makeup water would increase withdrawal from the Savannah River by 9 percent (1.8 cubic meters per second) over present withdrawal rates. Approximately 0.5 cubic meter per second would be released to Pen Branch.

Under extreme summer meteorological conditions, the overflow from High-Level Pond would have an exit temperature of about 35°C. Under average conditions, the temperature would be 34°C. This thermal discharge would impact biota in the 4-kilometer section of Pen Branch between the embankment and the stream's confluence with the K-Reactor thermal effluent (Indian Grave Branch), because the stream waters would be slightly above ambient. Ambient temperatures in Steel Creek would be unaffected by L-Reactor operation.

This alternative would not comply with the maximum 32.2°C State discharge temperature nor would it comply with the 2.8°C allowable temperature rise limit in Steel Creek.

Because this recirculation alternative would greatly reduce the thermal discharge to Steel Creek, it would result in a significant reduction of impacts to the biota of the creek, its delta, the floodplain, and the Savannah River in comparison to the effects caused by direct discharge.

The High-Level Pond would be similar to Par Pond. With time, a resident community of flora and fauna would develop from those hardy organisms that either were present before the impoundment or that might be introduced during the addition of makeup water.

After the impoundment, a portion of Pen Branch would remain as stream habitat between the High-Level Pond and the thermally impacted reach below K-Reactor. The stream flow and water temperatures in this portion would be affected little by the operations of K- and L-Reactors. However, surviving fish in this segment would become essentially landlocked; their access to upstream portions would be prevented by the High-Level Pond dam and their access to downstream portions and the floodplain swamp would be limited to periods of K-Reactor shutdown.

The High-Level Pond would inundate approximately 1175 acres of upland forest habitat, and about 610 acres of riparian wetlands associated with three headwater tributaries of Pen Branch. The wetlands that would be impacted by this alternative are classified as Resource Category 2 by the U.S. Fish and Wildlife Service. This resource category and designation criteria include "high value for evaluation species and scarce or becoming scarce" (USDOI, 1981). The mitigation planning goal specifies that there be "no net loss of inkind habitat value." Some acreage would be used for pipeline rights-of-way. This impoundment would not affect documented habitats of endangered or threatened species.

High-Level Pond makeup water would increase withdrawal from the Savannah River by 9 percent (1.8 cubic meters per second) over present usage. This increase would raise current impingement losses by about 956 fish per year and entrainment losses by 1.3×10^6 eggs and 1.9×10^6 larvae per year.

Radiocesium transported from Steel Creek is expected to remain at its current level of about 0.25 curie per year. Small quantities of cesium-137 would be transported from Pen Branch. In addition, the Savannah River would receive about 5820 curies of tritium per year from L-Reactor.

Nonradiological atmospheric releases would result in a maximum of 10 hours per year of reduced visibility (less than 800 meters) on the leeward side of the impoundment. No icing or salt deposition due to drift is expected.

This upland area characteristically has fewer archeological sites than floodplain areas. Eight to 10 sites, of which one or two would be eligible for the National Register are estimated to exist in this area; they would be subject to flooding. A mitigation plan would be developed and implemented prior to restart similar to that described for direct discharge.

The chemical characteristics of the overflow are expected to be similar to those of the waters of Pen Branch and the Savannah River, except the concentration of suspended solids would be lower. The water quality of the High-Level Pond should be similar to that of Par Pond. An ion-concentration (lake-to-river) ratio of 1.0 to 1.3 is expected for the High-Level Pond (Tilly, 1974).

The overflow to Pen Branch would not cause any erosion or sedimentation patterns to change in the stream or its delta because its flow would be increased significantly from its present level. Spoil from the surface portion of the embankment foundation in the Steel Creek floodplain, estimated to contain a total of 0.2 curie of cesium-137 and 0.02 curie of cobalt-60, would be separated, contained, replaced outside the jurisdictional wetlands upstream of the embankment, and covered with subsurface spoil to prevent erosion during the construction period. This relocation would have no effect on net cesium transport estimates. All uncontaminated material would be removed and used for

backfill in the borrow areas. Thus, any impacts on water quality and turbidity would be temporary until suspended particulates settle and bottom sediments stabilize.

This alternative would require the following permits or processes: (1) a U.S. Army COE 404 permit, (2) an SCDHEC 401 certification, (3) an NPDES permit, (4) a 316(a) demonstration, (5) consultations with the FWS, and (6) the preparation of a biological assessment for endangered species.

If this alternative is implemented before the restart of L-Reactor, the environmental impacts would be as described above. If it is implemented after direct discharge occurs, the environmental impacts would include those described in Section 4.4.2.2.1 for once-through direct discharge (i.e., loss of 730 to 1000 acres of wetlands, etc.) plus those (i.e., loss of 610 acres of wetlands and 1175 acres of uplands) resulting from the High-Level Pond alternative. Any mitigative effects resulting from this alternative would not begin until the end of the 48-month construction period.

4.4.2.4.4 Par Pond

Under this alternative, the existing Par Pond would be used to cool the effluent from both P- and L-Reactors. A pumping station similar to that required for the cooling-tower alternative, but with larger pumps (because of the longer distance) would be built south of L-Reactor (Figure 4-41). An underground discharge pipe from these pumps would run to the northeast to a knoll on the ridgeline between the watersheds of Pen Branch and Lower Three Runs Creek (Par Pond). At this point, the pipe would discharge into a new excavated canal similar to those constructed to carry P- and R-Reactor effluents to Par Pond. The new canal would follow the ground contours to the northeast to connect to Pond A near the R-Reactor effluent canal. From this point, the cooling water for L-Reactor would follow the same path through Par Pond that R-Reactor cooling water followed when that reactor was operating.

The Par Pond pumphouse served both P- and R-Reactors for some time but would require modification to serve both L- and P-Reactors; at present this pumphouse has a capacity for only one and a half reactors. Some new underground pipelines would be required to return Par Pond water to the L-Reactor reservoir. The amount of time required to design and construct this option should range between 30 and 44 months (Du Pont, 1982b). This alternative would use the same pumping system as the cooling-tower and High-Level-Pond alternatives. Therefore, the same 1-month shutdown would be required.

The estimated capital costs for the Par Pond alternative would be $104 million. Annual operating costs would be approximately $4.3 million. The present worth would be $178 million and the annualized cost would be $20.9 million (Du Pont, 1983d). An estimated 360 construction personnel would be required.

The relative production efficiency of Par Pond should be about 96 percent (derived from Du Pont, 1982b) of that for the direct discharge option. Water withdrawn from the Savannah River would increase by about 17 percent (3.5 cubic meters per second) over present usage by SRP, including the use of Par Pond for cooling P-Reactor.

Under extreme summer meteorological conditions (Section 3.1.1), the overflow would have an exit temperature of about 33°C, which is about 4° to 5°C higher than the maximum summer temperatures measured in Lower Three Runs Creek below Par Pond. During average summer conditions, the discharge would be at 31°C. Thus, only minor thermal impacts would occur to Lower Three Runs Creek or the Savannah River as the result of both L- and P-Reactors discharging thermal effluents to Par Pond. The thermal stratification and chemical cycling in Par Pond are described in Marshall and LeRoy (1971) and Alberts et al. (1979).

This alternative would not produce thermal impacts on Steel Creek. It would provide normal compliance with the maximum 32.2°C State discharge temperature limit.

Because this recirculation alternative would greatly reduce the thermal discharge to Steel Creek, it would result in a significant reduction in impacts to the biota of the creek, its delta, the floodplain, and the Savannah River in comparison to the effects caused by direct discharge.

Because Par Pond already exists, any modifications of terrestrial habitat would be limited to a temporary disturbance to approximately 50 acres to construct a new pipe discharge canal and pipelines. This 2700-acre lake, however, contains a diversified and abundant assemblage of aquatic and semiaquatic biota, including more than 100 American alligators (Murphy, 1981). This alternative would increase water temperatures in the north arm (former R-Reactor discharge arm) of Par Pond, and potentially displace the alligator and wintering waterfowl.

Increasing water temperatures in Par Pond in the summer could affect reactor operating power. The water withdrawal rate for both P- and L-Reactors (about 3.5 cubic meters per second) would cause the impingement losses of 1858 fish per year and entrainment losses of 2.5×10^6 fish eggs and 3.8×10^6 fish larvae per year.

Radiocesium transported from Steel Creek is expected to remain at its current level of about 0.25 curie per year. A small amount of radiocesium is transported from Lower Three Runs Creek to the river (Shure and Gottschalk, 1976; Gladden, 1979); this alternative could increase the rate of transport but only by a minor amount (i.e., 0.25 curie). In addition, L-Reactor would discharge about 3600 curies of tritium to Par Pond each year (Du Pont, 1982b); in addition, several curies of radiocesium would be remobilized from the R-Reactor cooling-water canal and lakes enroute to Par Pond. The total release of tritium to the Savannah River from L-Reactor would be 6270 curies per year.

Nonradiological atmospheric releases would result in (1) a maximum of 20 hours per year of reduced visibility (less than 800 meters) on the leeward side of the impoundment, and (2) a maximum of 15 hours per year of ice accumulation on horizontal surfaces. No deposition of salts due to drift is expected.

Four archeological sites are known to exist and an estimated four others would occur in the impact area. One of these sites would be subject to impacts caused by the reworking of the ground. A mitigation plan would be developed and implemented prior to restart similar to that described for direct discharge.

Little or no change is expected in erosion or sedimentation patterns in Lower Three Runs Creek because the overflow discharged to the creek would remain approximately the same as it is now and the creek bed is in equilibrium with this flow rate. There would be no change in the chemical characteristics of the overflow from Par Pond dam. Dredged material would be monitored and handled to meet applicable regulatory requirements. Thus, no adverse impacts to water quality, aquatic substrate, or existing turbidity levels would occur.

This alternative would require the following permits or processes: (1) an NPDES permit, (2) a 316(a) demonstration, (3) consultations with the FWS, and (4) the preparation of a biological assessment for endangered species. A U.S. Army COE 404 permit would not be required.

If this alternative is implemented before direct discharge occurs, the environmental impacts would be as described above (successional recovery of about 730 to 1000 acres of wetlands). If it is implemented after direct discharge occurs, the environmental impacts would be the same as those described in Section 4.4.2.2.1 for once-through direct discharge (i.e., loss of 730 to 1000 acres of wetlands, etc.). Any mitigative effects resulting from this alternative would not begin until the end of the construction period.

4.4.2.5 Other alternatives

The alternatives described below are not intended to be used alone, but rather in combination with either direct discharge (reference case) or one of the cooling-water mitigation measures.

4.4.2.5.1 Thermal cogeneration

Different thermal cogeneration systems were evaluated (ADL, 1983) for technical and economic feasibility at the Savannah River Plant. This study considered the following alternatives:

- Heat pumps for onsite steam generation
- Electrical production with Rankine cycles
- Onsite industrial applications in which private industry would construct new plants on SRP that would use the energy in the effluent streams
- Onsite agricultural/aquacultural applications
- Hot water delivery to offsite users

The study considers only the first two alternatives to be economically attractive. However, the thermal mitigation achieved by these alternatives is insignificant. If either of these alternatives is considered for installation, it would have to be justified on its own energy recovery.

Two different scenarios were considered for onsite steam generation. The first one would use an open-open cycle heat pump system to produce 1.9 kilograms per second of 275,790-pascal steam for use in L-Area. The preliminary cost

estimate indicated this option was economical. However, the option would remove only 0.3 percent of the heat from the effluent stream. This reduction amounts to an insignificant 0.3°C drop in effluent temperature at the outfall. Using the results, a preliminary assessment of using heat pumps to generate steam was completed (Du Pont, 1983g). The assessment made the following conclusions:

- The system would be unreliable for continuous operation because the reactor would not operate continuously.

- The steam from the river water would contaminate the system it served.

In summary, the heat pumps would have a minor thermal mitigation effect and appear to be unfeasible for SRP operation.

A Rankine cycle using ammonia as the working fluid has been proposed to generate electricity from the energy in the heated effluent. ADL (1983) discussed variations on the basic system.

The Rankine cycle would lower the effluent temperature from 71°C to 49°C. The effluent flow was assumed to be 11 cubic meters per second. For the Rankine cycle alone, 58 cubic meters per second of cooling water would have a temperature drop from 23°C to 19°C across its cooling tower. This tower design is a 14°C wet bulb, 9°C approach tower. The preliminary power output was revised in a followup study (Du Pont, 1983g) to be 29 megawatts.

Capital costs (ADL, 1983) for the Rankine cycle are $101 million. The Du Pont (1983g) estimate is $270 million. Approximately 8 to 12 years would be required for research and development, design, and construction of the Rankine cycle. Currently, the largest commercially available and proven units are in the 1-megawatt range and operate at source temperatures greater than 93°C (Du Pont, 1983g).

The Rankine cycle could also be used in a precooler mode (ADL, 1983), which would slightly improve the economics. In the precooler mode, the effluent leaving the Rankine cycle evaporator would be piped to a cooling tower. This tower would be separate from the Rankine cycle tower. Because of the low reliability of the Rankine cycle, the effluent cooling tower would be sized to handle the inlet water temperature directly from the reactor heat exchangers. By lowering the inlet temperature of the tower to 49°C, which is possible by the Rankine cycle, the coolant exit temperature from the tower would be approximately 0.6°C lower than when the inlet water temperature is 71°C. This lower exit temperature is based on using the 27°C wet bulb and 2.8°C approach cooling towers. If the cooling-water system was operating in a complete recirculation mode, the reactor power would be increased slightly. The increased reactor power would be worth $540,000 (Du Pont, 1983e) on a yearly basis if the complete recirculation mode was in use continuously.

The environmental effects of the Rankine cycle would differ depending on whether it was used alone or in a precooler mode. For the precooler mode, the environmental effects would be nearly identical to those described for the partial recirculation cooling-tower alternative, because similar amounts of water are being evaporated in both cases.

If the Rankine cycle is used in its standalone operation, a combination of environmental effects would occur for cooling towers and the direct discharge alternative. Because the Rankine cycle has its own cooling tower, the environmental effects of fogging, icing, etc., for cooling towers would be applicable. The reactor effluent would leave the Rankine cycle evaporator at 49°C and enter the L-Area outfall. This temperature is the equivalent of running L-Reactor near 1200 megawatts. The entire Steel Creek system at this reactor power would still be above 32.2°C. Because of the cooler water temperatures than those produced by the direct discharge case, larger backwater areas could exist with temperatures low enough to support aquatic biota. Other than this exception, the environmental impacts on Steel Creek for the Rankine cycle would be similar to those for the direct discharge case.

The ADL (1983) report also considered some Rankine cycle cases that would have altered the existing reactor heat exchangers. As with the heat pump cases, these variations are not economically feasible and could compromise reactor safety.

4.4.2.5.2 Low-head hydropower

Planning studies were carried out (Tudor Engineering Co., 1980) to evaluate the potential for hydroelectric power generation along the existing effluent channels that convey the cooling-water discharges from K- and C-Areas. The cooling-water discharge from each area is about the same as that for L-Reactor, and the effluent channels for each area convey the cooling-water discharges from an existing outlet pipe to a natural stream similar to L-Reactor. Therefore, the K- and C-Area studies as well as other studies (Jarriel and Price, 1979; Price, 1980) provided a basis for the following paragraphs.

Two locations for turbines were considered. Both are shown in Figure 4-42. The upstream location would include a penstock attached to the existing pipe that would carry the cooling effluent from the effluent sump to the outfall. This new penstock would bypass the outfall and discharge the effluent to Steel Creek downstream of the outfall. Energy would be generated by passing the water through a single hydroelectric turbine of the propeller type shown in Figure 4-43. The other location for a turbine would be below a new embankment impounding a 500-acre lake. The lake would provide cooling for reactor effluent before its discharge into the swamp and the Savannah River.

A turbine located beside the L-Reactor outfall would have a capacity of about 1100 kilowatts and generate about 7700 megawatt-hours annually. This power plant would cost about $11.5 million to construct. Annual operation and maintenance would cost about $100,000. The value of the energy produced was assumed to be $0.17 per kilowatt-hour. The project could be completed in mid-1985.

An alternative system for an outfall turbine would attach the turbine to a spray cooling pipe. The spray cooling valves would be closed during the late fall and winter, when they would not be necessary. With the spray cooling turned off, turbine generation would occur as it would in the conventional system beside the outfall. Some generation could be possible when the spray cooling system was operating. The savings in energy from hydroelectric generation for this alternative does not justify the additional cost.

If a 500-acre lake was built to allow once-through cooling for L-Reactor, it might be economically feasible to install a hydroelectric turbine in the outflow. The turbine would attach to the normal release from the lake and discharge into Steel Creek. There would be no temperature reduction due to the addition of hydroelectric power, but the economics of the 500-acre lake would benefit from energy savings.

A power plant below the embankment would have a capacity of about 1350 kilowatts and generate about 9440 megawatt-hours annually. The additional cost for the hydroelectric plant would be about $4.9 million. Construction would be complete only a few months after that of the embankment. The annual operation and maintenance cost would be about $100,000 per year.

Another alternative considered was construction of both the outfall plant and the plant below the 500-acre lake. For the combined system, the economic benefits of the plant below the 500-acre lake would be the same as those described above. The economics of the outfall power plant would be reduced due to the head reduction resulting from a higher tailwater (the 500-acre lake). For the combined system the outfall power plant would still cost about $11.5 million and could be complete in mid-1985. However, the capacity would be reduced to about 1000 kilowatts and annual generation would be about 7000 megawatt-hours.

The use of hydroelectric turbines along the discharge canal of L-Reactor would not reduce the thermal impact on Steel Creek or downstream wetlands. However, the hydroelectric turbines would utilize an energy source and could have a positive impact environmentally in reducing the use of fossil fuels at SRP.

4.4.2.5.3 Modified reactor operation

The total heat load discharged into Steel Creek is a direct function of reactor power. Therefore, power could, in theory, be limited to a level below that achieved at normal operating limits to control this heat load. As power is reduced, the temperature (under extreme summer conditions) would be reduced from about 80°C at the outfall for 2400 megawatts-thermal to 71°C at 2000 megawatts-thermal, to 53°C at 1200 megawatts-thermal, and to 40°C at 600 megawatts-thermal. The temperatures within the Steel Creek system would also be affected by reactor power levels. Simultaneous reduction of power and flow would increase the outfall temperatures higher than those reported above and, therefore, offer little benefit to the upper portions of Steel Creek.

While low power operation would not be practical for extended periods of time, it could provide a means of meeting thermal limitations for short periods. If the power were reduced, cooling-water flow could also be set to reduce either the total flow or the temperature of Steel Creek. At reduced power, production efficiency would be correspondingly reduced.

When modified reactor operation is used in conjunction with alternative cooling systems, the temperature of the effluent could be reduced further. For example, temperatures in the lower portion of the Steel Creek and in the swamp and Savannah River downstream of Steel Creek would be determined not only by the operating power and cooling-water flow of L- and K-Reactors, but also by the atmospheric conditions and river temperatures and flow. Thus, this option could be appropriate during periods of extreme meteorological conditions (such as occurred between July 11 and 15, 1980).

If extreme conditions combined to provide a thermal plume in the river that is large enough to threaten the zone of passage, then the power and cooling-water flow to either or both reactors could be adjusted.

4.4.2.5.4 Fisheries management programs

As discussed in Section 4.1.1, the reference case (direct discharge to Steel Creek) would have adverse thermal, entrainment, and impingement effects on some of the biological systems in Steel Creek and, to a lesser extent, the Savannah River. One option for mitigation of these effects would be the provision of replacement habitat or substitute individuals to compensate for the losses incurred. Although such losses would not be confined to one trophic level or group of aquatic organisms, the mitigation alternatives would focus on fish because of their commercial, recreational, or ecological value, and, in one case, their endangered species status.

This alternative would use the existing cooling-water system without any modifications and would have no effect on any impact of L-Reactor operation other than fish losses.

Based on recent Savannah River and Steel Creek surveys (ECS, 1983a,b; Smith et al., 1982), the fish species most likely to be affected by the various environmental effects associated with once-through cooling from the Savannah River and direct discharge to Steel Creek would be American shad, striped and largemouth bass, blueback herring, catfish and sunfish (Table 4-53).

Table 4-53. Fish species impacted by direct discharge to Steel Creek

Environmental effect	Potential fish species affected
Entrainment of fish eggs and larvae	Blueback herring, striped bass, American shad
Impingement of fish	Clupeids (shad and herring), centrachids (sunfish)
Loss of spawning/nursery habitat in Steel Creek/swamp system	Channel catfish, redear and bluegill sunfish, largemouth bass, blueback herring
Effect of Steel Creek thermal plume in the Savannah River	Blueback herring, striped bass, American shad

Other species that were considered for possible mitigation action include the Atlantic sturgeon because of its commercial value and the shortnose sturgeon because of its endangered species status.

Replacement mitigation alternatives would include the following:

- Restock impacted species either by an onsite fish hatchery or through a cooperative agreement with local state and/or Federal fish hatcheries.

- Protect wetlands similar to the Steel Creek/swamp system by purchasing or establishing a fisheries/wildlife preserve.

- Conduct or support research as part of a coordinated Savannah River fisheries management program and/or support the development of culturing techniques for fish species that are not currently being raised for restocking purposes.

4.4.2.5.5 Restocking

The criteria used to select fish species for mitigation alternatives include present and potential commercial and recreational value, ecological value, endangered species status, and existing culture capacity and/or culture feasibility. Table 4-54 identifies both the species and the criteria for their selection.

The ecological value criterion was based on present or potential importance to the Savannah River ecosystem without consideration of system-carrying capacity. The culture feasibility criterion included availability of broodstock, availability of hatching and rearing techniques and present production capacity of local hatcheries. Cost was not considered as a criterion for species selection; however, cost estimates are provided below after a description of the mitigation alternatives.

The Savannah River Plant has several sites that are suitable for fish hatching and rearing, including the Flowing Streams Laboratory on Upper Three Runs Creek and the Par Pond facilities. Both a hatchery facility and rearing ponds would be required. Well water at a flow rate of 760 to 1135 liters per minute would be required for the hatching operation; surface water would be suitable for the rearing ponds. Costs to modify an existing facility for the hatching operation would be approximately $250,000; the construction of a new facility would cost approximately $400,000. Construction of the 10 to 12 0.5-acre rearing ponds would cost as much $400,000. Annual cost to operate the facilities, including support for a fish hatchery biologist and two technicians, would be at least $250,000. Approximately 18 months would be required to design and construct the facilities. Depending on the fish species cultured, full-scale production could be achieved in 5 to 10 years. A wastewater-treatment lagoon could be required for rearing-pond effluent but would probably not be required for the hatching facility.

Based on the species selection criteria, American shad and/or blueback herring are the best candidates for an SRP hatchery operation. No local hatcheries currently exist for these species. Broodstock could be obtained by gill netting in either the Savannah River or Upper Three Runs Creek. Techniques for fertilizing the eggs and hatching the embryos are available. However, problems have previously been encountered in rearing shad and herring fry to stocking size because of their susceptibility to handling stress at this life stage. Stocking at the larval stage could be required to minimize handling mortality. Several local striped bass hatcheries are already in full production. Also, collection of striped bass broodstock would be difficult. However, striped bass fingerlings could be obtained from another source and reared in SRP ponds. Techniques for hatching and rearing Atlantic and shortnose sturgeon are not available, but are currently being developed at the Orangeburg National Fish

Hatchery. Obtaining and handling broodstock for these species would be a problem because of their low relative abundance and large size.

An alternative to using SRP land for hatcheries would be to obtain fish from local hatcheries. Both Georgia and South Carolina have hatchery facilities for striped bass, channel catfish, largemouth bass, and sunfish. A cooperative agreement could be established whereby SRP would provide support for the hatchery operation in exchange for fish of stocking size. The species and the number of individuals/species stocked would depend on estimates of L-Reactor impacts, mortality rate of natural and stocked fish, carrying capacity of the system stocked, and availability of hatchery fish. Cost of this mitigation alternative would be considerably less than the annual operating budget for an onsite hatchery (i.e., $100,000 per year).

4.4.2.5.6 Protect similar wetlands

If available, a property comparable in size and wetlands value to the impacted Steel Creek/swamp area could be purchased and set aside as a fisheries/wildlife preserve. Also, property of similar size could be set aside on the SRP site. Thermal discharges from L-Reactor could reduce the spawning/rearing habitat currently utilized by fish species in the Steel Creek/swamp system. Other creeks and associated wetlands with similar spawning/rearing habitat exist between the New Savannah Bluff Lock and Dam and the lower tidal reaches of the Savannah River. A large parcel of land (greater than 1000 acres) would cost approximately $500 per acre.

4.4.2.5.7 Support fisheries research

It could be desirable to conduct/support fisheries research. Thorough knowledge of the population dynamics and life history patterns of fish would be needed before good fisheries management decisions can be made. Recommendations for a fisheries management program based on a questionnaire completed by state and Federal fisheries biologists in the southeastern United States (Rulifson et al., 1982) emphasized these research needs. Additional research would also be required to develop techniques for hatching and rearing several species of importance to the Savannah River system, which include the shortnose and Atlantic sturgeon. A research program to collect fisheries data on selected anadromous fish species in the Savannah River would cost $150,000 per year. An additional $50,000 per year could be used to support the development of sturgeon culture techniques.

Initial costs (capital investment and construction), yearly operational costs, and total costs after 5 years are summarized in Table 4-55 for each of the programs described above.

4.4.2.6 Comparison of alternatives

Thirty-three alternative cooling-water systems were evaluated. The alternatives considered can be grouped into five major categories--once-through cooling lake, recirculating cooling lake, once-through cooling tower, recirculating cooling tower, and direct discharge. This section summarizes the engineering and environmental evaluations for the most favorable alternatives for each

Table 4-55. Yearly operational and total costs for mitigation alternatives

Mitigation alternative	Initial cost	Operation cost per year	5-year cost[a]
Restocking program			
SRP hatchery	$650,000	$250,000	$1,900,000
Agreement with local hatcheries	--	100,000	500,000
Fisheries/wildlife preserve	500,000	10,000	550,000
Support/conduct fisheries research	--	200,000	1,000,000

[a]Not adjusted for inflation.

category of cooling-water systems. This approach enables the reader to evaluate comparatively a range of reasonable alternatives, thus defining the issues and providing a clear basis for choice among alternatives. The criteria used in selecting the most favorable alternatives in each category are ability to meet South Carolina water-quality standards, production considerations, schedule, environmental factors, and the cost. Ability to expedite the schedule was also considered for these alternatives and the degree that reactor operation must be modified to meet State of South Carolina water-quality standards.

Seven once-through cooling-lake options were considered: small lakes, small lakes with upstream spray cooling, small lakes with upstream and downstream spray cooling, a 500-acre lake, a 500-acre lake with upstream spray cooling, a 500-acre lake with upstream and downstream cooling, and a 1000-acre lake. The 1000-acre lake evolved from the 500-acre lake in that it is the largest lake (thus providing better cooling and operational flexibility to comply with South Carolina water-quality standards) that could be constructed on Steel Creek in a single construction season (i.e., 6 months). For a lake size greater than 1000 acres, the construction schedule would be longer than a single construction season due to the need to build additional embankments and reroute major roads. The construction of the 1000-acre lake could also require more than one construction season if an unexpected delay occurred to the start of embankment construction. Thus, the 1000-acre lake is considered to be the best option for this category. Reduced reactor power levels would be required to comply with South Carolina water-quality standards (i.e., maintaining a balanced biological community in the lake). The schedule for lake construction can be greatly accelerated from the estimates given earlier because the U.S. Army Corps of Engineers (COE) has a staff readily available to design and construct the embankment to form the lake. This COE workforce is completing the construction of the Richard B. Russell Dam on the Savannah River and is now becoming available.

Four recirculating cooling-lake options are considered: a 1300-acre lake, Kal Pond, a High-Level Pond, and Par Pond. The Par Pond option is not considered further due to the significant impact on reactor operation for both P- and L-Reactors and the potential environmental effects on the Par Pond ecosystem. The 1300-acre lake option is considered to be the best because it requires the shortest time to implement with the least environmental effects.

Lake construction, however, would require more than one construction season. Reduced power operation would be required to maintain a balanced biological community in the lake.

For once-through cooling towers, three different designs--2.8°C, 5.6°C, and 8.4°C approach temperatures--for four different discharge options--discharge to Steel Creek, canal to swamp, spray canal and canal to swamp, and canal to swamp and pipe to the Savannah River--were considered. The 2.8°C approach cooling tower is considered the best because it has the lowest discharge temperature; direct discharge to Steel Creek is used in this comparison because it requires a minimum amount of time and cost to implement with the least impact on reactor operation (e.g., minimum annualized cost). Exceedances of the South Carolina water-quality standards of 32.2°C at the discharge point would be expected only rarely; however, a variance would have to be requested from the South Carolina Department of Health and Environmental Control (SCDHEC) for the 2.8°C temperature difference requirement. The schedule could be expedited to complete construction in slightly more than 1 year.

For recirculating cooling towers, three different designs--2.8°C, 5.6°C and 8.4°C approach temperature--for four modes of discharges--total recirculation with blowdown to Steel Creek, total recirculation with blowdown treatment prior to discharge to Steel Creek, partial recirculation with discharge to Steel Creek, and partial recirculation with refrigeration before discharge to Steel Creek--were considered. A discharge of the blowdown to Steel Creek without treatment would require a variance from the SCDHEC requirement for a delta-T of 2.8°C. The 2.8°C approach temperature with total recirculation and treatment of blowdown is used in this comparison because it meets South Carolina water-quality standards and causes the least amount of impact on reactor operation (e.g., minimum annualized cost).

Four direct discharge options were considered--direct discharge to Steel Creek (reference case), spray canal, penstock diversion to Pen Branch, and lake-canal diversion to Pen Branch. Because the spray canal would only provide a minimum amount of thermal mitigation, and because the two diversions to Pen Branch options would impact previously unaffected areas, direct discharge has been used in this comparison. DOE does not intend to pursue the option of direct discharge; its implementation would require either a reclassification of the Steel Creek system by the State of South Carolina or a Presidential exemption from the requirements of the Clean Water Act.

Table 4-56 compares engineering and environmental factors for the five alternative cooling-water systems--once-through 1000-acre lake, recirculating 1300-acre lake, once-through 2.8°C approach temperature cooling tower, recirculating 2.8°C approach temperature cooling tower with treatment of blowdown, and direct discharge. After considering all factors, DOE has selected the once-through 1000-acre lake as its preferred cooling-water alternative because it:

1. Meets all State and Federal regulatory and environmental requirements, eliminating thermal impacts on the river, swamp, and unimpounded stream, while providing a productive balanced biological community within the lake

2. Provides the earliest reactor startup and the maximum plutonium deliveries of any regulatory and environmentally acceptable cooling-water alternative

3. Has the lowest costs of any regulatory and environmentally acceptable cooling-water alternative

4. Is amenable to backfitting with precooler systems, if needed, which could improve reactor operational flexibility and the production capability.

The recirculating cooling tower alternative is considered the most favorable environmentally because it would not impact wetlands, the Steel Creek corridor, or uplands. This alternative was not identified as the preferred alternative, however, because it would require about 27 months to implement, even on an expedited basis; this would cause a large, unacceptable loss in material production. In addition, it would have a very high capital cost.

The recirculating cooling lake alternative is the next most favorable environmentally; its impacts are similar to those of the recirculating cooling tower, except it would inundate about 900 acres of uplands and 400 acres of wetlands. This alternative would have very high capital costs and a long schedule for construction in relation to that for the 1000-acre cooling lake. Even on an expedited basis (i.e., 18 months), the longer schedule would result in a large, unacceptable loss in material production.

The once-through cooling tower would have similar environmental impacts to those of the 1000-acre lake, except for the acreage inundated by the impoundment and the thermal shock effects of the discharge from the cooling tower on aquatic biota during startup or shutdown of the reactor. In addition, this alternative would have a longer construction schedule, with an attendant impact on material production, would have twice the cost of the 1000-acre lake, and would require a variance from South Carolina thermal standards.

4.4.3 Disassembly-basin water disposal

4.4.3.1 Background

The disassembly-basin water becomes contaminated when tritium and other radionuclides are carried over as process water adhering to the fuel and target assemblies and when tritium is contained as water of hydration in aluminum oxide on the assemblies. The disassembly-basin water is recirculated through sand filters and deionizers to clarify the water and remove radionuclides; tritium, however, is not removed in the process, and small residuals of other radionuclides also remain (Table 4-57). When the tritium content of the disassembly-basin water has built up to a procedural control level, the water is purged from the disassembly basin. Normally the basin is purged of as much as 1,890,000 liters of water following each reactor discharge. The purge is not continuous, but occurs at a frequency that depends on the type of reactor assemblies and the frequency of discharge operations; typically, the basin is purged twice each year.

Initially, the L-Area disassembly basin would contain very little tritium because the reactor would start up with a nontritiated charge of heavy water. The amount of tritium discharged would gradually increase as the tritium content of the reactor process water increases due to neutron activation. After about

Table 4-57. Expected average annual liquid releases of radionuclides to the L-Area seepage basin--tenth year

Radionuclide	To seepage basin (Ci/yr)	To Steel Creek from ground water[a] (Ci/yr)
H-3	[b]1.1×10^{4}	6.0×10^{3}
P-32	1.2×10^{-3}	--
S-35	9.5×10^{-3}	2.9×10^{-8}
Cr-51	1.8×10^{-1}	--
Co-58, Co-60	3.7×10^{-4}	2.1×10^{-4}
Sr-89	7.0×10^{-5}	--
Sr-90	2.0×10^{-4}	--
Y-91	5.1×10^{-3}	--
Zr-95	1.1×10^{-2}	--
Ru-106	3.4×10^{-4}	1.7×10^{-5}
Sb-125	8.0×10^{-3}	2.6×10^{-3}
I-131	6.9×10^{-3}	--
Cs-134	5.1×10^{-3}	--
Cs-137	4.4×10^{-2}	--
Ce-144	1.9×10^{-2}	3.8×10^{-4}
Pm-147	2.8×10^{-3}	8.8×10^{-4}
Unidentified beta-gamma	8.9×10^{-2}	--
Unidentified alpha	3.2×10^{-4}	--

[a]Outcrop activities after 15 years of L-Reactor operation. Due to long transport time in ground water, Sr-90 and Pu-239 would not reach outcrop until many years after L-Reactor operations have ceased. Estimated dose effects at this time are much smaller than those due to the listed radionuclides.

[b]Thirty percent of this tritium is expected to evaporate.

10 years of operation, the tritium content of the process water would approach an equilibrium; that is, the amount of new tritium produced would equal the amount lost through radioactive decay, leakage, and carryover during discharge operations.

The following subsections describe alternative disposal methods for disassembly-basin purge water and compare these methods on the bases of cost and offsite doses.